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A paper read at the 152nd Meeting of the American Institute of Electrical Engineers, New York, March 22nd, 1901. President Hering in the Chair.

THE DISTRIBUTION AND CONVERSION OF RECEIVED CURRENTS.

BY HENRY GORDON STOTT.

Before proceeding to the subject proper of this paper it will be interesting to give a brief description of the apparatus and lines generating, transforming and conveying the current from Niagara Falls to the Terminal House at the city limits of Buffalo, where the overhead lines terminate and the underground distributing system for the various purposes to be hereafter described, begins.

The power received in Buffalo originates at the well known plant of the Niagara Falls Power Company at Niagara Falls, N. Y., in water driven turbines direct connected to 5,000 H. P. two-phase 2,200-volt 25-cycle generators. Ten of these generators are now installed, and a new wheel pit is being excavated on the south side of the surface canal, parallel to the present power house, for twelve more generators of the same size, which will give an ultimate total capacity of 110,000 H. P., and it is a very safe prophesy to say that every horse-power of it will be sold as fast as the turbines and generators can be installed, as the present installation of 50,000 H. P. is all contracted for, and already many customers find themselves in the position of Oliver Twist, and with no better results.

The 2,200-volt two-phase current is conducted into the Transformer House, where, after passing through time element overload circuit breakers, it enters two distinct banks of step-up transformers of the air cooled type, of an aggregate capacity of 12,000 K. W., which are arranged in pairs for the two-phase

three-phase connection at the same time to change the pressure to 11,000 volts. Within a couple of months the secondaries, which are now in multiple, will be connected in series to give 22,000 volts as originally intended.

The 11,000 volt three-phase current from the secondaries of the two banks of transformers is brought directly out in cables on large special porcelain insulators set in iron fixtures in the air chamber, and then on the regular helmet type porcelain insulators on timbers on the wall. The lightning arresters are of the usual multi-gap type with reactive coils in series, and in a second type with an additional check to the current in the shape of carbon resistances to prevent the live current following the lightning discharge.

The two three-phase 11,000 volt circuits running on the same pole line to Buffalo, each consist of three bare stranded copper cables of 350,000 cm. area, forming equilateral triangles on each side of the pole, the sides of the triangles being three feet. In the run of 23 miles to Buffalo, the lines are transposed five times in order to equalize and minimize the inductive drop on all phases, and at Tonawanda where a branch line is taken off for Tonawanda and Lockport, lightning arresters are installed of a type similar to those used at Niagara Falls and Buffalo. During the first two years operation of this line, iron guard wires grounded at every alternate pole were used for protection from lightning, but so much trouble was caused by them falling on the lines that after striking a balance between the supposed protector and the known trouble, the result was so overwhelmingly against the former that the guard wires were taken down, and the interruptions due to line trouble very materially reduced. The remaining trouble on this part of the system was almost exclusively due to the ever present boy, who speedily discovered that by a little dexterity in the manipulation of an old piece of iron wire or hoop, he could produce brilliant Fourth-of-July effects at will. The cables were, at this time, only 18 inches apart, and an arc once established would travel backwards along the line with ease until the circuit breakers eventually opened at the Falls. This trouble was remedied very effectually by separating the cables three feet apart as at present, and at the same time arranging them so that they formed a triangle with the apex below instead of all being on the same plane as formerly.

At the Terminal House situated at the city limits of Buffalo, the lines now terminate in a common set of bus bars, and to these

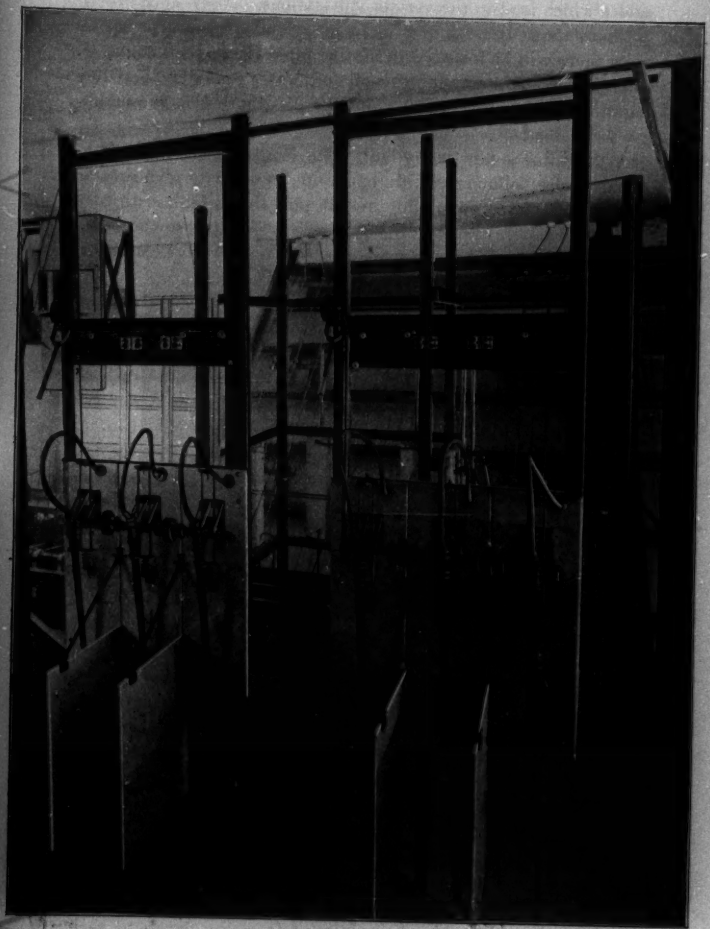


FIG 1.

bus bars are connected the five three-conductor lead covered cables which lead to the various sub-stations.

Simultaneously with the increase of line pressure to 22,000 volts there will be installed in the Terminal House six 2,250 K. W. step-down transformers of the oil and water cooled type, reducing the pressure to 11,000 volts for distribution in the underground cables.

A third line is now being built from Niagara Falls to the Terminal House, following a different route, in order to give greater security of service, but as the present pole line is built with very heavy poles 90 feet apart, no great anxiety is felt as to the possibilities of even Lake Erie zephyrs combined with sleet affecting it.

Following the current as it comes in the Terminal House on the 22,000-volt lines, we first come to the lightning arresters which are of the well known multi-gap type, the connections to each line having a reactive coil inserted to prevent the rush of static discharge being followed by a greater current, from the line, than the gaps of non-arcing metal can interrupt by cooling off the air and extinguishing the arc at the zero period of the wave. As an interesting fact it may be observed that the number of 1/32″ standard gaps necessary to prevent the current arcing across under normal conditions is not directly proportional to the pressure, but increases in the same ratio as the arcing distance in air of a single gap.

The high-tension circuit-breakers shown in Fig. 1 are of a very simple form, but one which has invariably given excellent results, being simply a long hollow wooden arm containing a flexible insulated conductor, which completes the circuit through copper contact blocks, with auxiliary carbon contacts for breaking the arc on. When the circuit-breakers open, the arm describes the arc of a circle giving a break of over three feet, and as the arc ascends rapidly, due to the currents of hot air generated by it, the length of the arc is rapidly increased until broken. The position of the marble barriers above the panel illustrate the height to which the arc may be expected to rise in extreme cases. After passing through the circuit-breakers the current is led to bus bars, and from these to the two groups of transformers only three cables being carried from the panels to each group of three transformers, as the delta connection is made at the terminals. The low tension, or 11,000-volt secondaries are

connected in the same way to the bus bars on the secondary panels, and from here the five three-conductor lead covered cables distributing the current to the various sub-stations in Buffalo, receive their current after passing through the usual recording and indicating meters and circuit-breakers of the same type as on the 22,000 volt side. All these circuit-breakers have a time element device which can be regulated so as to make the circuit-breakers open only after a short-circuit has lasted a predetermined number of seconds; similar devices are used on all over-

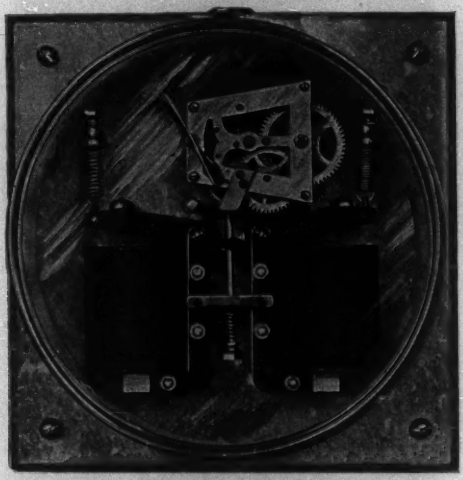


FIG. 2.—A view of one of the time element relays. The two coils are connected respectively with current transformers in two phases of the line. Either releases the clockwork which after a proper interval closes a local circuit through the tripping coils of the breakers.

load circuit-breakers, the time limit varying inversely as the distance from the source of power, in order to prevent the more distant stations shutting down the others.

We now come to the distribution and conversion of the current in Buffalo, but the scope of this paper will only permit of the more important and novel features being taken up and described in the briefest manner possible.

Distribution.

Referring to the diagram, Fig. 5, showing the system of distribution connecting the seven sub-stations to the Terminal House, it will be seen that there are five three-conductor cables leaving the

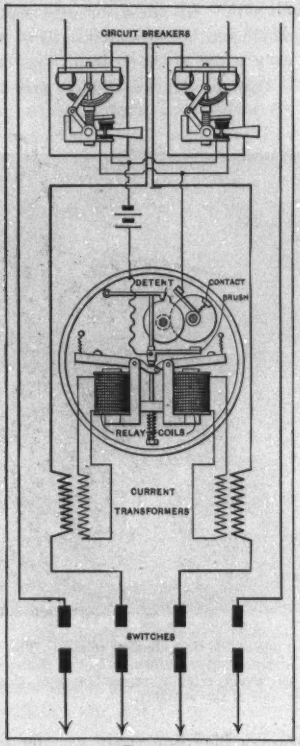


Fig. 2a.

Terminal House, each sub-station being connected to at least two cables, either one of which is capable of carrying the full load, and in the other stations having more cables, any two are capable of carrying the full load. The necessity for duplicate service to prevent shut-downs through cable trouble, is so obvious

as to necessitate no further comment, but the automatic apparatus used to cut out the faulty cable is novel and interesting. Before describing the system a brief description of the various circuit-breaking apparatus used will be in order.

Figure 1 shows a type of breaker used in the Terminal House and in sub-station No. 3, which has already been described; Figs. 2 and 2A, show one known as the shunted fuse type, in which the current is carried by a spring copper leaf brush which is forced into

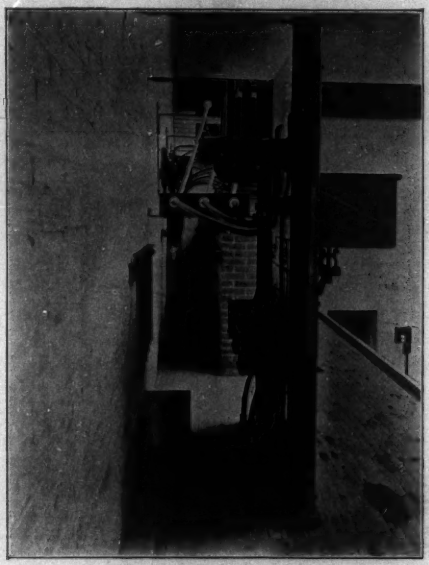


FIG. 2B

contact with the copper blocks by means of a toggle joint lever. In shunt with this is a copper fuse wire 20″ long of No. 22 B. & S. gauge fastened in a groove in a stick having near each end brass contacts, which, when the fuse stick is forced into the receptacle mounted in the marble panel, forms a shunt on the circuit-breaker proper. The fuse stick is covered with fibre paper, and three holes are punctured through this paper, so that when the

stick is in place in the enclosing wooden tube, the holes in the paper exposing the copper wire, are opposite three fibre chimneys. The gases formed by the melted copper escape with such force through these chimneys shown in Fig. 2B, that the arc formed after the circuit-breaker trips, is blown out with a noise resembling the report of a pistol.

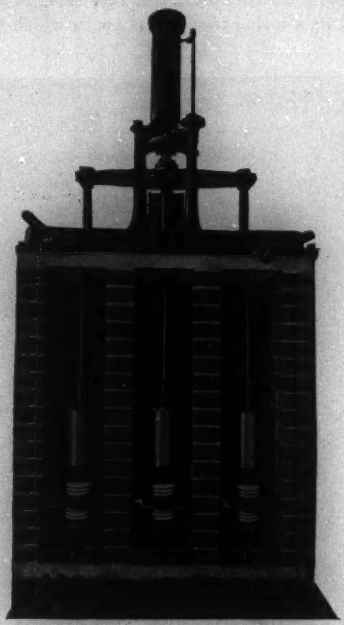


FIG. 3.

To reset the circuit-breaker, the switches in series with it are opened, the old fuse stick replaced by a new one, the circuit-breaker closed, and last of all the switches. This form of circuit-breaker has given excellent results on both 2200 volts and 11,000 volts. A time element relay is shown in Figure 2, which is used on the overload apparatus, the retardation being accomplished by a train of clockwork operated by an

ordinary spring. The brake on the clock train (which is normally at rest) is released by either of the two magnets, one being connected to the secondary of a transformer in series with phase No. 1, and the other similarly connected to phase No. 2, the diagram showing the connections for a two-phase circuit. Variation of the time limit is accomplished by changing the angle of the air paddles on an axis normal to the spindle driving them.

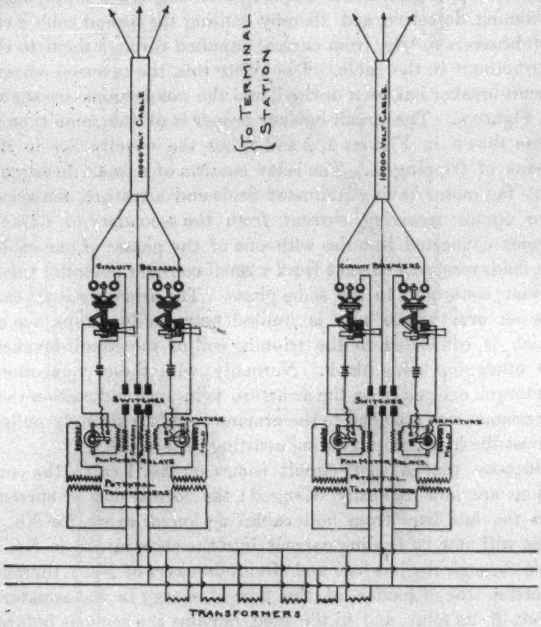


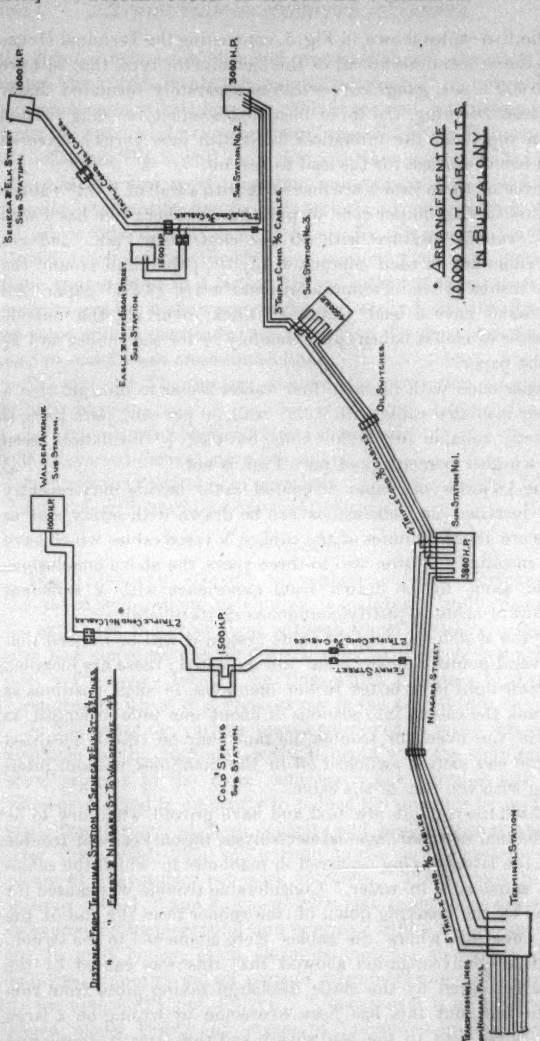
FIG. 4.

Figure 3 shows a third type of switch which may be operated by air, controlled by a relay or by any other agency, and consists simply of a U-shaped copper rod connecting two brass cylinders, with spring sockets, filled with oil. When the U-shaped rods are withdrawn from the copper receptacles at the bottom of the cylinders the arc is broken in oil in two places.

The cut illustrates the separation of the phases by means of brick partitions, so that in case of failure a short-circuit cannot take place. These switches have also given excellent results on all pressures.

It is quite obvious that any sub-station supplied from two cables in multiple through overload circuit-breakers, is thoroughly protected from damage due to failure of apparatus in itself, but a few moment's consideration will also show that it is not protected from a shut-down due to one of the cables supplying it becoming defective, and thereby causing the second cable's circuit-breakers to trip, from current supplied through them to the short-circuit in the cable. To obviate this, the reversed current circuit-breaker has been devised, and the connections are shown in Figure 4. The circuit-breaker proper is of the same type as those shown in Figures 1, 2 and 3, but the novelty lies in the means of tripping it. The relay consists of a small direct current fan motor having laminated fields and armature, the armature circuit receiving current from the secondary of a transformer connected in series with one of the phases of one cable, the fields receiving current from a small constant potential transformer connected to the same phase. The armature shaft carries an arm whose play is limited between two stops, one of which is connected to the tripping coil of the circuit-breaker, the other stop being blank. Normally with these connections the torque exerted upon the armature is in such a direction that the contact arm attached to the armature shaft is strongly pulled against the blank stop, a spring assisting in this pull.

Suppose that a short-circuit comes on No. 1 cable, the conditions are now radically changed; the normal flow of current into the bus bars from both cables no longer exists, for No. 2 cable will now be feeding current into the short-circuit in No. 1 cable through the bus bars and circuit-breakers of No. 1, thereby reversing the direction of the flow of energy in the armature circuit of its relay, and as the field remains the same as before, the contact arm swings over rapidly, completing the local circuit and tripping the circuit-breakers, leaving the sub-station bus bars connected to the good cable only. The same action will take place at all the sub-stations to which this cable may be connected, and finally the overload circuit-breakers in the Terminal House will cut out the faulty cable entirely.



* Arrangement Of 10000 Volt Circuits In Buffalo Only.

FIG. 5.

The five cables shown in Fig. 5, connecting the Terminal House with the sub-stations are all of the 3-conductor type, that is, have three 000 B. & S. gauge copper cables separately insulated under one lead covering, the three insulated conductors being twisted into a rope, and the interstices filled with jute yarns to give an even round surface for the lead to rest on.

Three of these cables are insulated with a wall of 9/32″ rubber mixture having 30 per cent. of pure Para rubber; one has a wall of ¼″ rubber mixture with 40 per cent. pure Para, and the fifth cable has on each conductor 13/64″ paper, and around the three insulated conductors an additional belt of 13/64″ paper. All the cables have a lead jacket ⅛″ thick, over all, the outside diameter of cables being approximately 2⅝ for the rubber and 2⅝ for the paper.

Experience with the first four cables seems to indicate that a rubber insulated cable with 9/32″ wall, 30 per cent. pure Para, is perfectly reliable for 11,000 volts, but that ¼″ insulation even with a higher percentage of pure Para is not.

The 18 miles of paper insulated cable having only recently been installed, no conclusions can be drawn with safety, but as there are about 30 miles of the rubber covered cables which have been installed for from two to three years, the above conclusions would seem to be drawn from experience with a sufficient amount of cable to justify confidence in its reliability.

In the sketch showing the cable system it will be noticed that at several points "oil switches" are indicated; these are installed in water-tight iron boxes in the manholes, in such positions as to break the cables into sections of about one mile in length, so that in the event of trouble the fault may be readily localized and the bad section switched off in the manholes without interfering with the rest of the cable.

Glazed tile conduits are used, and have proved, when dry, to be an effectual safeguard against electrolysis, the only cases of trouble from the latter having occurred in manholes in which the cables were submerged in water. Considerable trouble was caused for a time by the breaking down of the rubber near the end of the lead covering where the cables were connected to the switchboards, and investigation showed that this was caused by the ozone generated by the static discharge taking place from rubber to lead, but this has been overcome by wiping on a large brass cable head to the lead sheath and thus greatly increasing

the distance between rubber and grounded sheath, the cable head being filled with insulating compound poured in hot, a hard rubber separator keeping the rubber covered conductors away from the brass whilst the compound was solidifying. Reference to the diagram Fig. 5, will show that a further precaution has been taken at the two most important sub-stations, Nos. 1 and 3, to prevent interruption due to cable trouble, viz., to run loops from all cables into them instead of taps. By this means, if a fault should simultaneously develop in a section of one cable between these stations and in a section beyond either of them, cross-connections can be made very rapidly and easily by means of which no cable will be overloaded for more than the short period necessary to make these cross-connections.

To sum up: The means adopted for protection to the distributing system are:

1. Time element overload circuit-breakers.
2. Reversed current circuit-breakers.
3. Sectioning switches in manholes.
4. Loop switches in principal sub-stations.

Conversion.

The 11,000-volt 25-cycle three-phase current distributed to the seven sub-stations in Buffalo is manifestly unfit for use in the supply of power or light without transformation in the former and conversion in the latter case, as 25-cycle is much too low a frequency for arc lighting, which promises to displace incandescent lamps to a great extent in the near future.

In discussing the various means employed to make this power available to the customer, we will begin with the simplest and then proceed to the more complex. The simplest and most efficient method is evidently to reduce the pressure by means of static transformers of large capacity and high efficiency and deliver three-phase 2200-volt current to the various customers by means of a secondary net work of cables. This is done in sub-stations Nos. 1, 2 and 3, where 2200-volt three-phase current is delivered by underground and overhead cables to customers for use in malt houses, grain elevators, machine shops, dry docks, bakeries, tanneries and all sorts of manufacturing establishments to the extent of about 4,000 H.P. This power is utilized in the above places chiefly by means of induction motors, some of which receive the current directly at 2200 volts, but in the ma-

jority of cases at a reduced pressure of 440 or 220, the reducing transformers being supplied by the customer. For grain elevators, in which a large amount of fine dust of an explosive nature is present, the induction motor presents an ideal solution of the power problem as the safety and controlling devices can be located in a separate building, so that no spark can cause an explosion or fire. The efficiency of transformation with this system is evidently that of the transformers only, which in sizes of 250 K.W. and upwards is from 97.5 to 98.3 per cent. at full speed.

The largest user of power in Buffalo is the International Traction Company, which receives a total of 7000 H.P. in five sub-stations, No. 1, Cold Springs, Walden Avenue, Eagle and Jefferson streets, and Elk and Seneca streets, where the power is distributed to their 550-volt direct current feeders after being transformed from 11,000 volts to 375 volts and converted in rotary converters to 600-volts direct current.

An interesting comparison is the relative efficiencies and cost of static transformers and rotary converters as against motor generators receiving the 11,000-volt current direct into the motor, and converting it into 600-volt direct current by means of a generator coupled to the same shaft, and is given in the following table:

EFFICIENCIES: 200 K.W. UNITS.

	Transformer	Rotary	Combined	Motor	Generator	Combined
Full load	97.5	93.0	90.67	95	92	87.4
¾ load.	97.1	92.5	89.81	94	91	85.54
½ load.	96.0	90.0	86.40	92	88.5	81.42

From the above table it will be seen that the transformer and rotary converter give 3.27 per cent. at full load, 4.27 per cent. at three-quarter load and 4.98 per cent. at one-half load better efficiency than the motor generator set.

The investment shows a saving in favor of transformers and rotary converters of about 19 per cent., so that for purposes such as railroad work, where no great refinement of regulation is required, the rotary is beyond doubt the best and most economical.

A view of a sub-station is given in Fig. 6, which is typical

of all; the incoming current enters a three-pole oil switch, which is known as an emegrency switch, and from there branches to several oil switches, each of which controls the primaries of three 150 K. W. static air-blast transformers connected in delta; the secondaries, also delta-connected, go direct to the collector-rings of a 400 K. W. rotary converter, so that the three static transformers and rotary converter form one unit, being in fact started from the direct-current end and synchronized by means of small potential transformers on the 11,000-volt primaries.

FIG. 6.

To provide for the emergency of a total shut down of the power circuits, those sub-stations which have no storage battery auxiliary from which direct current may be got for starting the rotaries, a small motor generator set is installed, consisting of a 30 H. P. induction motor direct-connected to a 20 K. W. 600-volt direct-current generator. This set is supplied with alternating current by means of a three phase oil-cooled transformer, reducing the pressure from 11,000 to 375 volts; as soon as the power is on the cables the induction motor is started, the small direct-current generator is connected to the

bus-bars and one of the rotaries started and synchronized in the usual way, after which the motor generator set is shut down and the remaining rotaries started from the first. From the five sub-stations distributing power to the direct-current feeders great economy of distribution is obtained and an equality of pressure at practically every point of the system, which would be practically impossible with a single plant with 550-volt feeders covering the same distance. Storage batteries are installed at Sub-stations No. 1, Cold Springs and Eagle and Jefferson, having a total capacity for 1½ hours of 2,400 H. P.

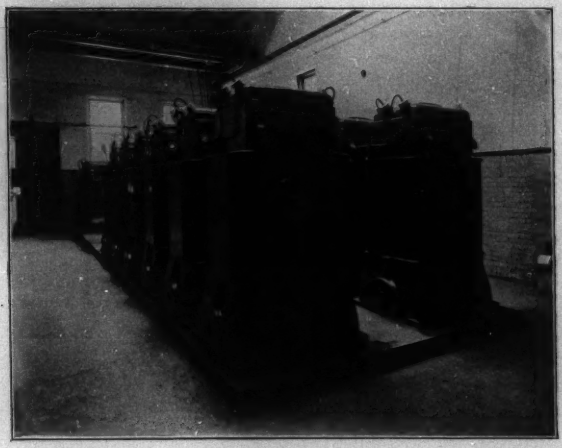


FIG. 7.

at 575 volts. They are used principally to help carry the peak load between 5 P. M. and 6.30 P. M. and to take up part of the extreme fluctuations of load through differentially wound boosters.

We now come to the last and most interesting plant connected to the transmi-sion system in Buffalo, viz., that of the Buffalo General Electric Company, the transformer-house of which is marked "Sub-station No. 3" on the sketch showing cable system, in which 4,000 H. P. is received from the power company, and after being transformed to 360 volts is con-

verted, by means of motor generator sets, rotaries, etc., into four different kinds of service—constant continuous current for street arc lighting, 60-cycle quarter-phase current for incandescent and arc lighting in the more remote districts, three-wire 220-volt continuous current for the down-town district, and 550-volt continuous current for power to motors, elevators, etc.

The transformer-house, built as an annex to the main station, has twelve 250 K. W. transformers, reducing the three-phase

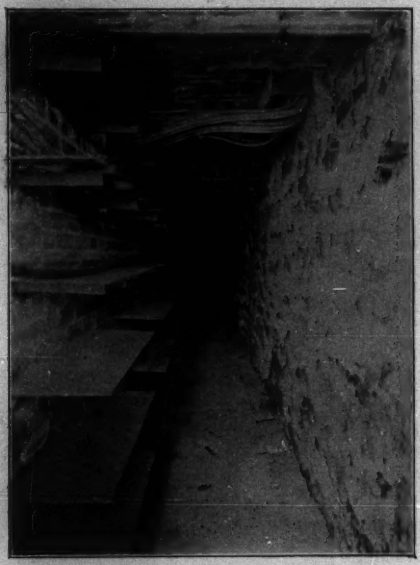


FIG. 8.

11,000-volt current to three-phase 360 volts. The transformers [see Fig. 7] are arranged in two rows instead of three as usually in order to facilitate the rapid exchange of one in case of trouble. By arranging them in this way the transformer has only to be raised half an inch by the hand-crane and then run out of the way to make room for the spare one, an operation requiring only an extremely short period compared to that necessary to

lift the transformer over the others. The transformers stand over a brick air-chamber 30′ x 9′ x 7′ high, into which three 2 H. P. induction motors direct-connected to air-blowers force cool air, giving an even pressure of about half an ounce in all parts of the chamber. Access is had to the air-chamber through double air-tight doors, so that a man can work on the terminals or connect up a new group without interfering in any way with the air supply. Iron shelves on the outside of the brick walls of the air-chamber form supports for the primary cables leading to the switchboards on the one side and for the secondaries on

FIG. 9.

the other, giving wide separation for safety, similar to those in Fig. 8.

The transformers are connected to the primary and secondary switchboard panels by rubber insulated and lead covered cables; each transformer is wired single-phase to the panels, the delta connection being made after passing through spring expulsion type aluminium fuses on the primary side, and ordinary long break aluminium fuses with barriers on the secondary side, so that in the event of a transformer burning out it will cut itself out of circuit without affecting the other two of the same group.

The secondary current after going through the usual recording and indicating instruments, terminates in three heavy copper bus bars, extending the full length of the secondary board, to which are attached the cables bringing the current into the main building of the Buffalo General Electric Company.

In adopting the secondary voltage of 360, a number of points were taken into consideration, the principal one being that a large and healthy day load in 550-volt direct current motors was being supplied at the time steam was used for motive power, and could not well be discontinued, so that voltage was adopted which would permit of rotaries being run without any further transformation. This pressure besides being very safe for cables and motors, is a very economical one to build for, as it permits of the use of bar winding on all sizes, and as all motors are of the revolving field type, the question of carrying heavy current in the collector rings was left out. The only additional cost due to the low pressure was in the cables within the plant, and this was more than balanced by the saving in a further transformation for the 550-volt rotaries and in the additional safety of bar winding versus wire.

The power house, Fig. 9, is a building 91′x91′, having a row of columns down the center, each half of the building being spanned by a crane traveling the full length with transfer points from one crane to the other.

In this building having 8281 square feet of floor surface are installed 6460 H. P. in motors, 6073 in generators, and 600 H. P. in rotaries, a total of 13,133 H. P. in electrical machinery, giving a floor space of 0.63 square foot per H. P. or 1.24 square feet per H. P. of generating capacity, including all regulating apparatus, switchboards, etc.

Apparatus for Street Arc Lighting.

At the present day if the problem of arc lighting for street purposes with 25-cycle three-phase current supplied, were to be placed before an engineer, several methods of solution would suggest themselves in the following order: 1st, rectifiers; 2d, motor generator sets, converting to 60 cycles constant potential with some form of transformer or reactive coil to regulate for constant current; 3d, motor generator set converting to constant continuous current; 4th, motor generator set converting to constant alternating current with series transformers and condensers.

The full load efficiencies of the four systems with comparative investments and full power factors are approximately as follows:

1	2	3	4
Rectifiers.	Motor Generators 60 Cycle.	Motor Generators Constant D. C.	Motor Generators Constant A. C.
88	83.94	78.9	86.6% Efficiency.
53	100	94	94 % Investment.
70	100	100	100 % Power Factor.

From the above table it will be seen that the rectifier leads in all respects save one, viz., power factor (the power factors given are those of the 25-cycle end, the receiver power factor

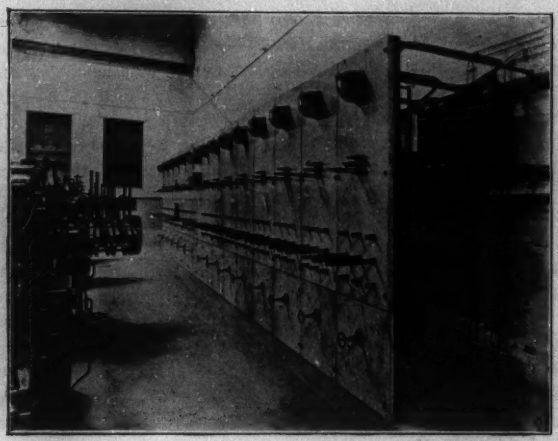


FIG. 10.

being of small importance), but in a system where the arc lighting forms a considerable portion of the system this is a serious feature, especially with generators not having good inherent regulation.

Owing to existing contracts with the city, the company was forced to adopt the third plan, but after the expiration of the present contract it will probably adopt the fourth plan, installing enclosed A. C. lamps.

The arc lighting equipment at present consists of 14 motor generator sets, each set consisting of one 150 K. W. revolving

field type three-phase synchronous motor direct-coupled to two 125-light 9.6 ampere Brush arc generators, the motor being in the center, with a generator on each end, coupled by means of a very simple but effective type of insulating coupling, consisting of four arms or spiders on the motor-shaft and a similar number on the generator, compressing spring rubber rolls $3\frac{1}{2}''$ in diameter by $4\frac{3}{4}''$ long between them.

These motors are started in a very simple manner. The switchboard panel, shown in Fig. 10, controlling each motor has mounted on it one ammeter, one double pole field switch

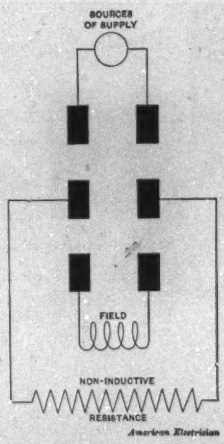


FIG. 11.—Circuits of switch shown in Fig. 10.

with discharge resistance as shown in sketch, Fig. 11, three single pole double throw knife switches and a rheostat. The fuse base is mounted on the back. Fastened to the wall behind each panel are the reactive coils for starting the motor.

To start the motor the three single pole switches are thrown down, thus connecting the motor armature to the bus bars through the reactive coils; the motor comes up to full speed in about 50 seconds, taking at the start about 150 per cent. full-load current. The time of attaining synchronism is determined by touching the blades of the field switch connected to the revolving fields on the discharge resistance clips and noting

if any spark occurs. In the absence of any, the field switch is closed, exciting the fields and the single pole double throw switches turned up one at a time (the motor running single-phase meanwhile).

The spark at the discharge resistance terminals is of course due to the difference in frequency or slip between the impressed frequency and that due to the speed of the motor. At the start this gives about 2,200 volts, dying down in inverse ratio to the speed attained, to zero, at synchronism.

FIG. 12.

550-VOLT POWER SERVICE.

The 530-volt power service is supplied from rotary converters [Fig. 12], in the usual way, calling for no comment beyond the method of starting from the A.C. end which is done in exactly the same way as in the synchronous motors; the fields being stationary, a multiple blade switch is mounted on the frame of the machine to isolate each field winding, and thus break up the induced E.M.F. at starting.

60–Cycle System.

Three 500-K.W. three-phase synchronous revolving field type motors direct connected to 500-K.W. revolving field 2200-volt quarter phase generators, furnish the current for this system. The feeders are connected to double throw oil switches, so that they can be thrown from one phase to the other to balance up the load, a further control of the voltage being obtained by means of regulators on each phase. Some rather unusual prob-

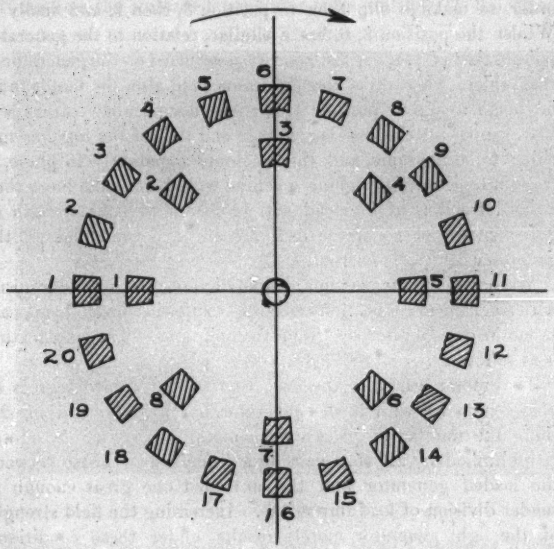


Fig. 13.

lems presented themselves in synchronizing these 60-cycle generators. The motors having eight poles and the generators 20, it is evident from the sketch, Fig. 13, that only every fifth pole of the motor will be the proper point to lock at. At first it was supposed that by opening the field switch on the motor that it would slip a pole when the generator field was excited, and the whole iron losses act as load, but the voltmeter showing the resultant voltage between the bus bars and the ingoing genera

tor refused to move. The synchronous motor was too good a hysteresis and reaction motor, but the solution was found in putting in a reversing field switch on the motor, thus causing it to slip a pole on each reversal. The inner circle, shown in Fig. 13, represents the motor poles, and the outer the generator. If the generator carrying load has its poles in the position 1, 1, at the moment the field switch on the motor about to go into service is closed, and the latter locks with 1, 1, in the position of 4, it is evident that we must reverse the motor fields several times in order to make it slip back to position 3, then 2, and finally 1. Whilst the position 3, 6, has a similar relation to the generator pole, to that of 1, 1, yet the polarity is reversed on the generator so that unless we reverse the generator field also, the motor must be made to slip to position 1, 1. Another peculiar feature was that supposing the bus bar voltage and that of the ingoing machine to be the same, and the machines apparently in phase, if thrown together the ingoing machine would not take more than a small fraction of the load, and no change of field strength of either motor or generator had any effect, beyond making the generator carry idle current.

We have here the peculiar combination of double synchronism, with mechanical connection besides, so that either machine may act as motor or generator according to conditions. The explanation is as follows:

The motor carrying the load sags behind a few degrees of phase, carrying with it the generator, but the latter having 2.5 times the number of poles of the motor, any sag of the motor is multiplied by 2.5, thus causing a difference of phase between the loaded generator and the unloaded one great enough to render division of load impossible. Increasing the field strength of the light generator merely results, under these conditions, in the unloaded generator supplying idle cross current out of phase with the bus bar current, and therefore not putting load on its own motor. Manipulation of the motor field rheostats can evidently accomplish nothing to bring the generators into phase.

The solution is a rather startling one, and is found in the use of oscillating currents. The in-going generator is excited to such a degree that the resultant voltage from it and the bus bars is equal to the latter; this means at half load on one, and the other light, an increase of 4 per cent. in voltage, indicating

a phase angle difference of about 22.5 in the generators and 9° sag in the motor. The motor fields are weakened and the unloaded generator thrown on the bus bars. Owing to the difference of voltage and phase, the sudden closing of the circuit establishes strong oscillatory currents between the generators; these are transmitted mechanically to the motors and repeated, the amplitude gradually decreasing from a maximum value of 100 per cent. full-load current to zero as the equilibrium of the circuit is established. The whole time, from the moment of putting the unloaded generator into multiple to the disap-

FIG. 14.

pearance of the oscillations, is usually about 45 seconds, during which the field strengths of the generators and motors are rapidly equalized, and the load will be found to be perfectly divided between the two generators, the mechanical oscillations having resulted in the only stable equilibrium possible under the conditions.

EXCITERS.

Before the installing of the storage battery it was necessary to have some quick means of getting continuous current, to determine the polarity of the rotary converters and energize

the fields of the synchronous motors in case of a shut-down on the power circuits, and for this purpose two exciter sets consisting of 30-H. P. induction motors direct-connected to 20-K. W. 125-volt continuous-current generators were installed. Since the installation of the battery, all the exciting current is taken from it during the period of heavy load, for two reasons; first, to reduce the peak load; second, to automatically maintain an almost constant power factor of 98 per cent. leading, on the total load of the plant, due to the Edison load increasing (and bus bar pressure increasing correspondingly) simultaneously with the other station load and thus giving increased C. E. M. F. in the motors.

FIG. 15.

EDISON SYSTEM.

There are evidently two ways of converting three-phase 25-cycle current into 120 to 150-volt continuous current, one being by means of transformers with rotary converters, and the other with motor generator sets.

A comparison of the net efficiency of both systems for 200-K. W. units is given in the following table, the rotary including in its circuit some form of regulators capable of varying the voltage 25 per cent.:

	Motor Generator.	Transformers and Rotaries.	Difference.
Full load.....	87.40	89.87	2.47
Three-quarter load..	85.54	88.70	3.16
Half load.....	81.42	84.90	3.48

Owing to the additional regulating apparatus necessary with the rotaries, the first cost in either case is practically the same.

From the above efficiencies, rotaries would seem to be indicated as the best choice, but in an extensive power transmission scheme where nearly 50 per cent. of the load is used for railroad purposes, and the generators have a comparatively poor inherent regulation to enable them to withstand safely severe short-circuits on the lines, rotaries have had to be abandoned for this service,

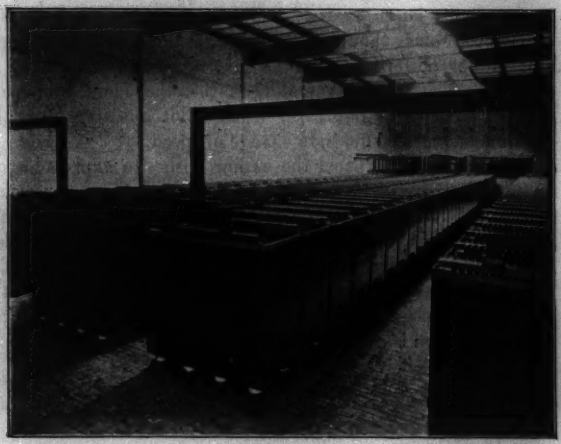


FIG. 16.

every fluctuation of the line potential being reproduced on the direct current side. Two 100 K.W. rotaries were installed, but additions have been made to the system only in motor generator sets, two of which are installed, the first of which is a direct connected set consisting of a 425 K.W. motor coupled to two 200 K.W. generators, [Fig. 14], having a very wide range of voltage to permit of charging the battery direct without the intermediary of a booster; the second, now being installed, is an 850 K.W. motor direct coupled to two 400 K.W. generators.

A 150 K.W. booster set consisting of a synchronous motor coupled to two direct current boosters is used for charging purposes, and for carrying long feeders. The storage battery has a capacity for one and a half hours of 6000 amperes at 150 volts, [Fig. 16], there being 75 cells on each side of the system with two 20 point end all switches [Fig. 15], on each side to give control of the pressure under varying load.

A peculiar point observed is that a motor generator set and rotaries operating in multiple on the direct current side, tend to regulate one another, with varying speed, for constant potential. The rotary being practically independent of speed; a fall of speed or frequency on a transmission system having a large amount of inductance reduces the reactance, and a rise in speed increases the latter so that but for changes in the impressed voltage the rotary should give the best results on a system driven from water power in which the governors must of necessity be sluggish. The motor generator, on the other hand, is independent of changes in impressed voltage, but sensitive, especially with undersaturated fields, to change of speed.

In concluding this paper the author wishes to express his obligations to the *American Electrician* for permission to use cuts; to Mr. P. F. Sellers of the Cataract Power and Conduit Co., for outline drawings, and to Mr. G. A. Harvey of the General Electric Co. for photographs.

Much matter, which could, under a strict construction of the title, have been put in has been left out, and matter which in the author's opinion is more interesting and practical substituted.

A paper read at the 153d Meeting of the American Institute of Electrical Engineers, New York, April 26th, 1901. President Hering in the Chair.

THE TRANSFORMER FOR MEASURING LARGE DIRECT CURRENTS.

BY HARRIS J. RYAN.

In operating practice, the use of the transformer for the measurement of large alternating currents is now widely adopted. No similar operating use of the transformer can be made for direct currents. This paper, however, presents *a method for large direct current calibrations* that employs the transformer for comparing the values of large and small currents in terms of the ratio of transformation and the reading of the instrument used for measuring the small current. The method is based upon the following principle:

Where two direct current carrying coils of similar dimensions are placed side by side and linked with a closed laminated iron core of low reluctance, the permeability of this core for alternating magnetic flux will be a maximum when the ampere turns of the two coils are equal and opposite.

The test for maximum permeability to alternating flux may be applied in various ways. I have found the one given by the diagram of Fig. 1 to work very well. In this diagram A-1 is an ammeter that has been recently standardized by reference to the Clark cell and a Reichsanstalt resistance. A convenient range for this instrument is from 0 to 25 amperes. With reference to A-1, the heavy direct current shunt and milli-voltmeter type of ammeter is to be calibrated, checked or adjusted. The ampere turns produced by the small current drawn through the secondary coil, B, mounted on the core, C C, and the ammeter, A-1, are to be balanced against the ampere turns produced by the large current through the single primary turn, A, and the

ammeter, A-2. In circuit with A-1 and B there is a water rheostat conveniently arranged so that the current on this circuit may be smoothly yet quickly adjusted to any desired value. The auxiliary primary and secondary circuits, a and b, the two two-part commutators mounted and driven on the same shaft, and the galvanometer, G, are for the purpose of noting when the permeability to alternating flux of the core, C C, is a maximum, as the current in A-1 and B is changed to bring the ampere turns of B equal and opposite to those in A due to the large continuous current.

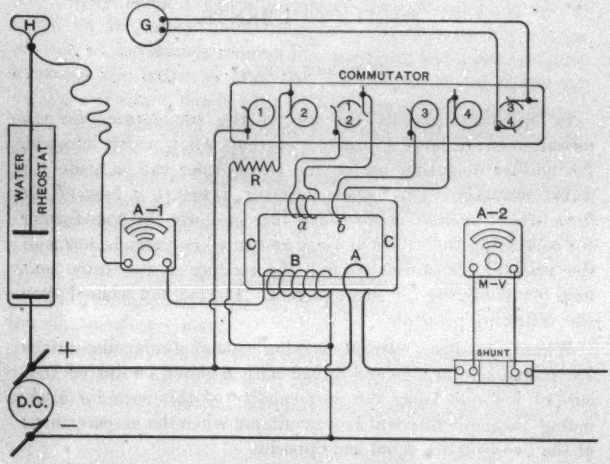


FIG. 1.

The alternating current through the primary, a, which provides the necessary small alternating M.M.F. is obtained by passing a direct current of one or two amperes from the large direct current source, D.C., through the controlling resistance, R, the revolving two-part commutator, 1-2, and as alternating current through the small auxiliary primary, a. The secondary, b, contains one turn which connects with alternating current through the revolving two-part commutator, 3-4, and with rectified current through the galvanometer, G. The two-part commutators are mounted and driven on the same shaft. The brushes of

these commutators are set on diameters that are at right angles to one another. Thus b is definitely connected to the galvanometer, G, at each reversal of the current that occurs through a. In our trials of this method we drove the commutator shaft from a fan motor. The commutators can easily be made light enough to be driven by clockwork if so desired.

At a given commutator speed and current running through a, the galvanometer, G, will give a maximum deflection when there are no currents in A and B, or when the ampere turns of those coils are equal and opposite. To determine the current in A-2 in terms of A-1 an observer at the galvanometer adjusts the current through A-1 and B by means of the water rheostat until a maximum deflection is obtained at G, at which point the instru-

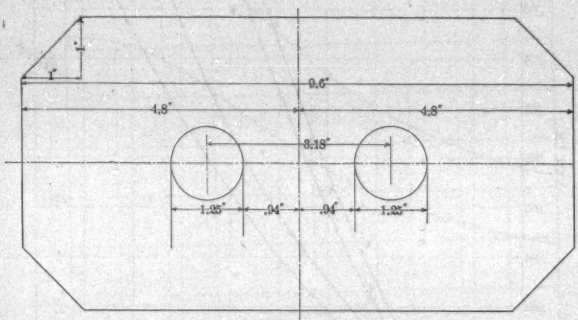


FIG. 2.

ments, A-1, and A-2 must be simultaneously read. The value of the current through A-2 is the current through A-1 multiplied by number of turns in B,—A having one turn.

TRIAL OF THE METHOD.

A transformer for this purpose was constructed having the following specifications and dimensions:

The Core.—The core was built of .016″ Apollo transformer japanned steel sheets. The shape and size of each sheet are given in Fig. 2. Total number of sheets, 117.

The Current Coils.—For convenience in checking the results, a ratio of transformation of unity was adopted, *i. e.*, the coils A and B as indicated in the diagram of Fig. 1, consisted each of 15 turns of No. 10, B & S. G.

The Alternating Induction Coils.—The coil, *a*, contained 27 turns of No. 18 B. & S. G., and the coil, *b*, contained one turn.

The transformer was connected with testing circuits and facilities in all respects as described in connection with Fig. 1. The galvanometer used at G is a "Queen Portable" that gave a deflection of one small division per .0008 volt. It has a range of 15 small divisions, plus or minus.

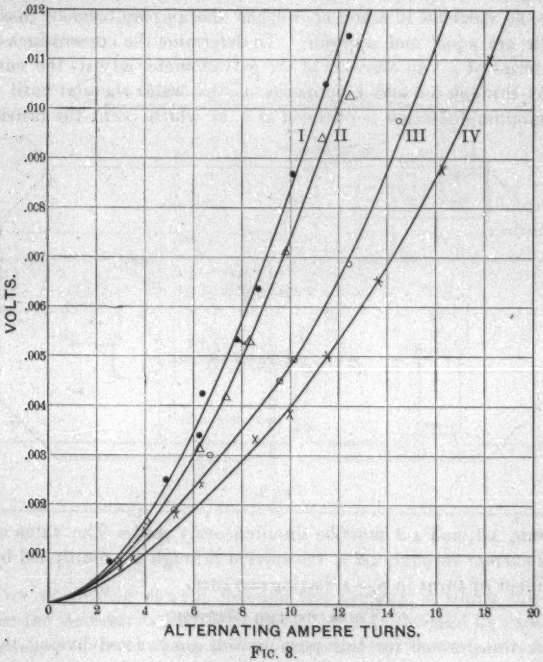


FIG. 8.

FIRST EXPERIMENT.

A series of observations was first made to determine the sensitiveness of the core to changes in permeability for alternating induction when subjected to direct current M.M.F's. in either of the coils, A or B., under the action of various magnitudes of alternating M.M.F's. The results of these observations are given by

the curves in Fig. 3. For example, curve I was obtained by applying different values of alternating current through the coil, *a*, see Fig. 1, and at each value observing the reading of the galvanometer, G, when no current was passing through either current coil, A or B. Curve II was obtained in the same manner except that a small direct current was passing through *one* of the current coils, *i. e.*, either A or B. The amount of this current was

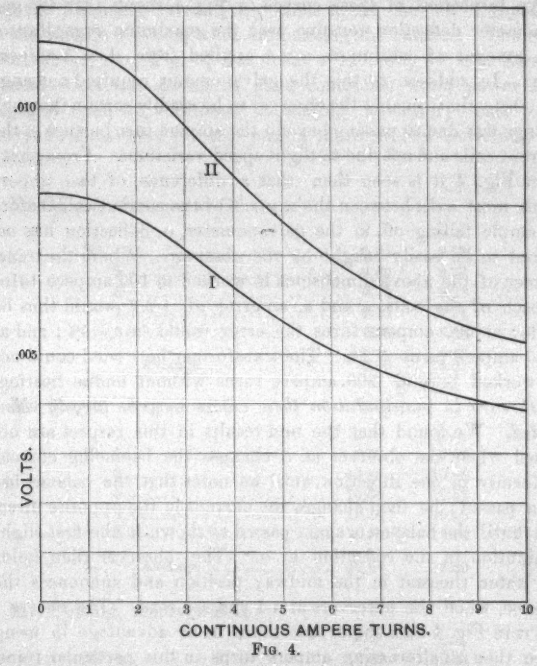


FIG. 4.

such as to produce in 15 turns a M.M.F. of 2.8 ampere turns. The remaining curves, III and IV were determined in the same manner for M.M.F's. in one of the current coils of 6.62 and 9.91 ampere turns.

An inspection of the curves enables one to determine the number of alternating ampere turns that should be applied as a minimum for observing when the continuous current in the coils

A and B are equal; likewise approximately the accuracy obtainable with this method. Thus at 10 alternating ampere turns the volts obtained at G are read from each of the curves I, II, III and IV of Fig. 3. These values when plotted with their corresponding continuous current ampere turns maintained in one of the current coils, form the curve, I, drawn in Fig. 4. In the same figure, curve II is correspondingly drawn for 12 ampere turns.

An inspection of these curves in Fig. 4 shows that the galvanometer deflection remains near the maximum regardless of the amount of continuous M.M.F. applied from 0 to 1 ampere turn. In addition to this the galvanometer required a change of .0004 volts to enable the observer to be readily certain that such change was due to passing beyond the ampere turn balance in the current coils and not due to slight speed variations. From curve II in Fig. 4 it is seen then that a difference of two ampere turns must exist between the M.M.F.'s of the current coils before an ample falling off in the galvanometer, G, deflection has occurred to be easily caught by the observer. Where the transformer of the above dimensions is worked to 100 ampere turns in each of the coils, A and B, an error of $\pm 2.\%$ would thus be made; at 500 ampere turns the error would be $\pm .4\%$; and at 1000 ampere turns $\pm .2\%$. The transformer here tried could not be worked beyond 200 ampere turns without undue heating. *With care in manipulation these errors may be largely eliminated.* We found that the best results in this respect are obtained when the observer at G changes the balancing current uniformly in one direction until he notes that the balance has been passed; he then changes the current in the opposite direction until the balance is again passed as shown in the first slight diminution in the reflection at G. The observer then holds the water rheostat in the midway position and announces the balance, when the observers at A-1 and A-2 read. The curves I and II in Fig. 4 also show that there is no advantage in using more than 12 alternating ampere turns in this particular transformer through the coil, *a*.

Second Experiment.

In this experiment a trial was made to determine identical currents in the coils A and B. Two Weston 15-ampere ammeters were used for A-1 and A-2. They were carefully compared with one another by passing current through them in series.

A continuous current was set up through A, and current was turned on through B, and adjusted until G indicated a maximum at which moment A-1 and A-2 were read. The following tables give the observations made in this manner by various observers as stated, who manipulated the water rheostat, and announced the balance observed at G. Each observer was instructed to pass the balance in both directions by increasing and decreasing the balancing current, and then to set the water rheostat in the middle position, when announcing the balance. The current source, D.C., Fig. 1, was from a 125-volt, 50 K.W. Edison dynamo that was driven by hand controlled water power and engaged upon an additional fluctuating laboratory load. All current values were for this reason more or less constantly on the move:

Mr. Hoxie, observer at G:

	A—1.	A—2.
No. 1	9.95	9.93
2	9.80	9.77
3	9.75	9.75
4	9.70	9.74
5	9.75	9.84
Average	9.79	9.81

Mr. Norris, observer at G:

	A—1.	A—2.
No. 1	9.60	9.62
2	10.48	10.48
3	10.55	10.57
4	10.54	10.49
5	10.56	10.34
Average	10.35	10.30

Mr. Cowing, observer at G:

	A—1.	A—2.
No. 1	10.40	10.34
2	10.41	10.40
3	10.40	10.40
4	10.44	10.45
5	10.41	10.43
Average	10.41	10.40

It is seen that the errors thus made range from plus two-tenths of one per cent. to minus five-tenths of one per cent.

Third Experiment.

A number of trials were made to determine the effect of external magnetic forces upon the point at which the balance would be indicated. A 1,000-ampere-turn coil was placed on the transformer core in a number of positions, and trials for a balance of the current in A and B were made, with the current "on" and "off" through the disturbing coil, and no perceptible effect was observed.

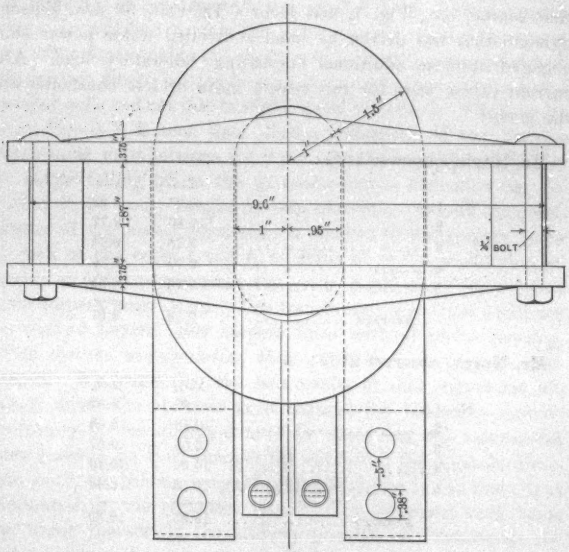


Fig. 5.

It was thus determined that errors due to external M. M. F's would not occur in the application of this method under all ordinary conditions that are present on switchboards for heavy currents.

This did not, however, determine that errors are not due to internal magnetic leakage, since in this experiment when the ratio of turns was unity, magnetic leakage was purposely eliminated by winding side by side the two conductors forming the

two coils. Thus the coils were thoroughly interlaced and could not produce appreciable magnetic leakage.

It was necessary then to determine the error due to magnetic leakage which in the ordinary transformer gives rise to transformer self-induction. For this purpose I used a transformer that had been designed to work as an alternating current multiplier. It was intended to multiply the current range of a 25-ampere instrument 40 times, so that it could be used in a 1,000-ampere circuit. Transformers for such purpose do not have to approach perfection in the elimination of self-induction. The construction of this transformer is given in Figs. 5, 6, 7, 8 and 9. The construction details given in these figures are so complete that no further description is necessary.

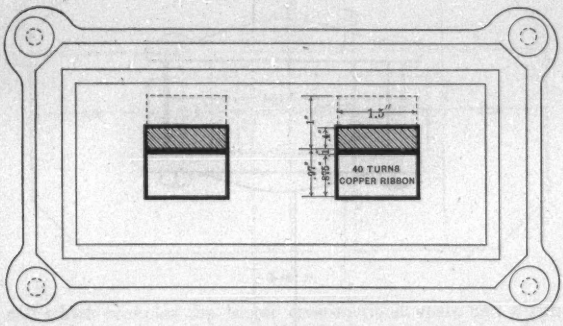


FIG. 6.

It should be noted that the peculiar construction of the 1,000-ampere single-turn coil where it passes through the core is for the purpose of lessening as much as possible, the primary and secondary conductor cross-sectional area that must be enveloped by the core. Thus the core reluctance is diminished to a minimum—a very desirable feature for an alternating current multiplier. This is accomplished by the loss of some additional E. M. F. through magnetic leakage or transformer self-induction—a point not important, as stated above, in current multipliers.

This transformer is well-suited for trial to determine the effect of internal magnetic leakage upon the accuracy of the direct-current transformer-balance. Currents up to 1,000 amperes were

furnished from a 2-volt direct-current generator through the single-turn coil, and balancing current was supplied through the 40-turn coil from a 110-volt direct-current machine. The heavy current was measured by means of a British Board of Trade .0001-ohm, 1,000-ampere resistance standard and a Weston millivoltmeter that had been calibrated by reference to a Carhart-Clark cell.

The balancing current was measured in the same manner, using a .01-ohm Reichsanstalt low resistance standard and a millivoltmeter, also calibrated by reference to the standard cell. The

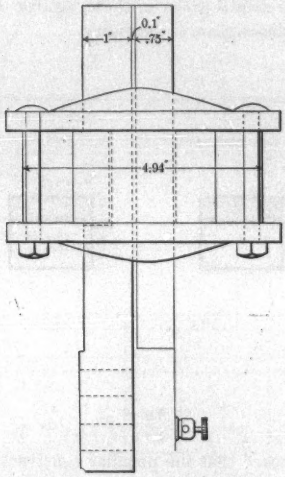


FIG. 7.

British and German resistance standards were compared with one another and found to be in agreement. The following results were obtained:

Amperes.	Ampere Turns.	Ratio.
40.6	40.2	1.010
157	154	1.020
500	476	1.051
648	621	1.044
1035	996	1.039

Each set of the above results was obtained by taking the average of five balances and simultaneous sets of readings.

To those who are particularly concerned with all matters relating to the magnetic circuit, the column of ratios will be very interesting when studied in connection with the dimensions of this transformer. Most persons, however, will care for no further comment on the meaning of these ratios than that *pronounced internal magnetic leakage will produce errors amounting to as much as five per cent.*

A study of these results taken in connection with the construction of the transformer brought out the manner in which magnetic leakage produces this error. The error is due to the fact that the

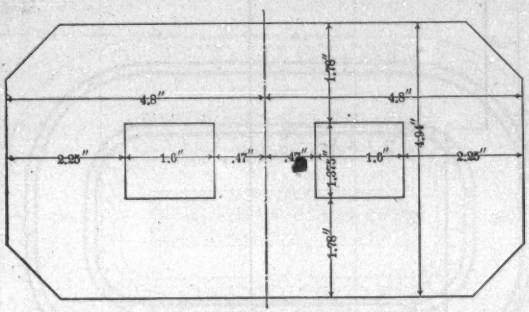


FIG. 8.

coil which occupies the larger cross-sectional space and which is the seat of the larger magnetic leakage behaves toward the one which occupies the smaller cross-sectional area as though it had more than its real number of ampere turns. The phenomena within the iron of the core where there is this unbalanced magnetic leakage may be analyzed, and the result obtained will show that the coil occupying the larger space will have apparently more ampere turns than the actual number present when the attempt to balance is made.

A type of transformer must therefore be selected which will avoid magnetic leakage as far as possible, and such leakage as does occur must be equal for each coil.

FORM OF TRANSFORMER ADOPTED.

The form of transformer that will avoid magnetic leakage

errors, and which is conveniently applied under most practical conditions is illustrated in Fig. 10. Upon the laminated core are wound the ampere-turn balancing coil, and the few primary and

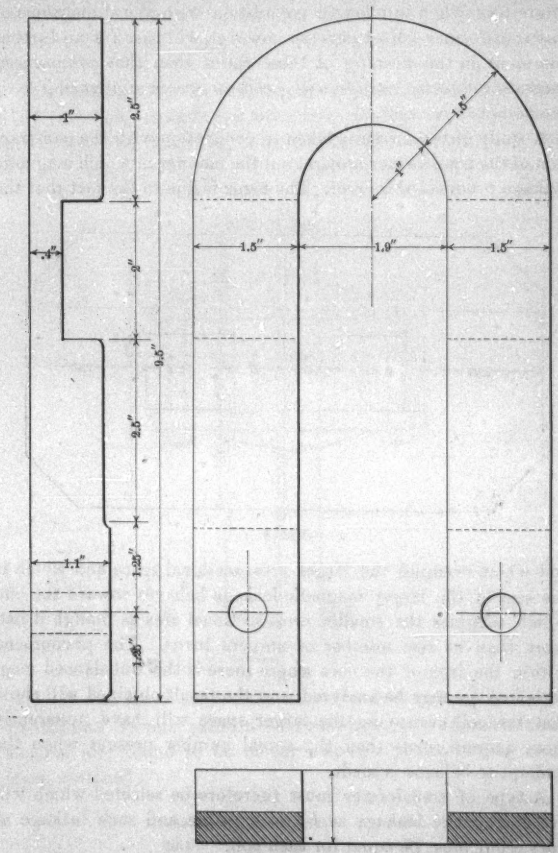


FIG. 9.

secondary turns for the alternating balance test. The core when wound is so shaped as to form a link that makes an easy fit over

the heavy conductor which carries the large current to be determined.

In Fig. 10 there is a single view of a transformer of this kind that Prof. J. O. Phelon constructed and assisted me to test.

The core is one-half inch square and one-quarter square inch in cross-section. The material in the laminations is continuous; no magnetic joints can be allowed in these cores. The laminations were cut from 14 mil Apollo electrical steel sheets.

The alternating primary contains 20 turns, and the secondary 10 turns.

The heavy direct current conductor measures $2\frac{5}{8}''$ by $\frac{9}{16}''$. The ampere turn coil is wound with 68 turns of No. 10 B. and S. cable.

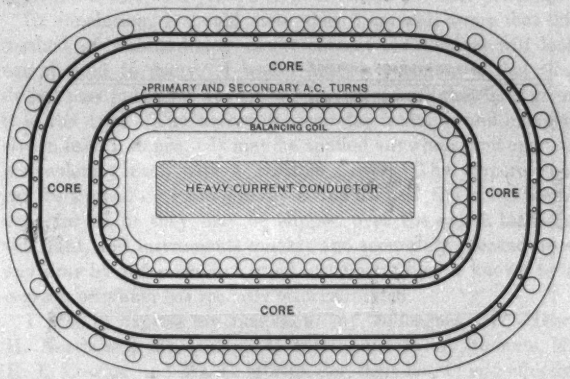


FIG. 10.

The mean length of the core is approximately 12 inches. The primary alternating current was supplied by 1.25 amperes of direct current passed through the two-part commutator. The alternating ampere turns applied to the core were, therefore, 25, or about two alternating ampere turns per inch of core. I usually drive the commutator from a small motor at a speed of 500 R.P.M.

In testing this transformer for error, the same instruments, standard and current sources were employed as when testing for the error due to magnetic leakage.

The following results were obtained:

Amperes.	Ampere Turns.	Ratio.
238.7	238.7	1.0000
712.6	713.2	.9991

Each of the above set of values is the average of five sets of readings taken at five corresponding balances.

These excellent results were obtained by taking current from a fluctuating power source *i. e.*, the pointers on the ammeters suffered a steady drift to and fro so that the exact balance lasted for a moment only.

It must always be remembered that this is a zero method. Thus an error is introduced if the current either in the heavy or light circuit suffers a momentary and periodic fluctuation

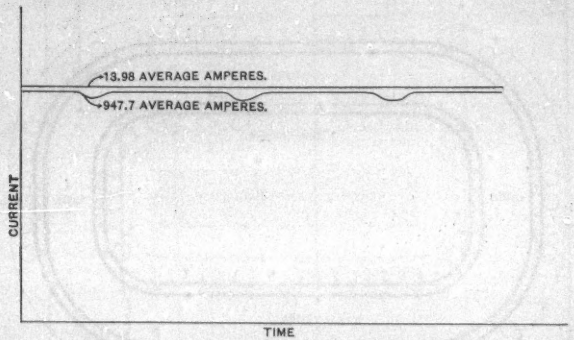


FIG. 11.

that is not common to both circuits. For example, when the current in the last test was increased to 950 amperes, trouble at the commutator of the 2-volt machine appeared. The brushes and commutator are too small for the delivery of so large a current. The pointer on the heavy current instrument showed a momentary periodic depression as indicated in Fig. 11. Since the balancing current had to be furnished at a higher pressure than two volts, it was taken from a separate 110-volt generator. The balancing current suffered no corresponding fluctuation in value. It is evident that the balance would be obtained at the higher value of the fluctuating heavy current. Since the instrument indicates the values of the average currents, it follows that the ampere turns in this instance will be too high. To study

this source of error the current of 950 amperes was passed long enough to obtain five sets of readings. The following result is the average of this set:

Amperes.	Ampere Turns.	Ratio.
947.7	951.7	.9958.

The error due to this cause in this instance was, therefore, .4 per cent.

In practice, a case of this sort is not likely to be found. Where there are periodic and momentary fluctuations of the heavy current, the balancing current will be drawn from the same source, suffering practically the same fluctuations, thus eliminating the error. The above instance in our test is a highly aggravated case, and yet the error is within one half per cent.

In conclusion, I should state that I am well aware that this method of standardizing direct current instruments will look complicated to many. I would heartily recommend that they do not pass judgment upon it in this respect until they have given it a fair trial. The necessary apparatus is simple and inexpensive in each instance. It may be applied anywhere, and operates conveniently even with a variable power. The ampere links can be slipped over the circuits at the back of the switchboards once for all, or they may be slipped over the switch blades at the front, and instruments quickly and accurately checked up at any time by reference to a small instrument that is known to be correct, or which has recently been calibrated.

I wish to express my thanks to my colleagues, Mr. Henry H. Norris and Mr. George L. Hoxie, and to my students, Mr. H. E. Cowing and Mr. F. Martin, for their hearty and effective co-operation in conducting the experiments which resulted in the development of this method for the determination of large direct currents.

Department of Electrical Engineering,
Sibley College, Cornell University, April, 1901.

A paper read at the 153d Meeting of the American Institute of Electrical Engineers, New York, April 20th, 1901. President Hering in the Chair.

ELECTRICITY IN MOUNTAIN MINES.

BY F. W. BRADY.

As the theories which are fundamental in the generation and transmission of electrical energy have been very largely represented in the proceedings of the INSTITUTE in papers of more or less heavy character, the writer has thought that it would not be out of place to present a descriptive article. The purpose is to give the particulars and details of a few plants illustrating the general conditions and difficulties to be encountered in making three different kinds of installations, a classification depending upon the location of the mines, viz., those reached only over burro trails, those by aerial wire rope tramways, and the ones having wagon roads of various grades and conditions.

In the Rocky Mountain district there are a large number of electric mining plants ranging from that of a single diamond prospecting drill to those operating a great variety of machinery and requiring several hundreds of horse power. Although there are some restrictions to its use, the application of electricity in such plants is ideal, in fact, any other style of operation is prohibitive. Wood, water and coal are not available in many cases, and the mines are located frequently on the face of precipitous cliffs, and inaccessible except over a trail or an aerial tramway. While this is true of those already equipped, there are other mines waiting for similar improvements, cases where it is necessary for some one to "Find out mens' want and need, and meet them there."

The use of electricity has greatly improved the methods of working the mines and gives a corresponding increase in their

value. A large number now have electrically lighted tunnels and mine buildings, electric driven hoists, air compressors to operate drills and forges, pumps, drills, blowers and mills. Of course electricity in mining operations, like its applications in all other industries, has been a gradually progressing science, its present perfection being the outcome of many trials and failures, mistakes and disappointments.

Beautiful creations of the designer, the founders' art, and the machinists' pride have left the assembly room with cheers for "bon voyage," but alas never to perform a useful service, unless 'tis "mens' want and need" to increase the dump of some mine or add to the momentum of an avalanche of tin cans in the mountain gulches.

Imagine, if you can, a cast iron drum 4½x5 ft., weighing 3500 pounds, and made all in one piece, to be transported over a burro trail, places in which a tenderfoot would hesitate to tread! Such designs have a delightful car ride of more than 1000 miles only to find a final resting place two or three miles from the mine where intended to be used.

The first requirement in making such mining installations is to get reliable data of the capacity of the water power. Generally the plants installed far exceed the power available to drive them. The report of the constructing engineer should be very elaborate, not only regarding the water power, but also conditions in the mine, the methods of transportation, special requirements in design of apparatus, maximum weight of parts and dimensions, the topography of the district for pipe lines, transmission lines, etc. As mountain streams are so variable, it requires measurements for a period of several years to get any reliable basis to work on. From the very nature of the case, such installations are far from the base of supplies and in locations often where little or no mechanical or electrical work had ever been previously attempted. Even at best, an unlimited number of schemes and devices must be worked out on the spot to facilitate the transportation, construction and operation of the plant.

It must be understood that in making any legitimate installation the purchaser from his standpoint insists upon quality of apparatus and construction and certainty of operation, the plant filling the needs of the mine in all the particulars guaranteed before its adoption. On the other hand, the contractor wishes

the plant erected at minimum cost, and to be promptly accepted and paid for.

The plant of the American Nettie Gold Mine, of Ouray, Colo. is a good example of an installation in which all the mine machinery and most of the materials for the transmission line were transported from the railway over a burro trail. The source of power for the plant is the Uncompahgre River, a dashing mountain stream fed by springs and heavy snows from a very large area of an intensely rugged range. There is a considerable variation in the volume of the flow of the stream, the lowest being in February and March, when there is the least thaw and the streams are frozen. The flow at this time was found to be 960 cubic feet per minute. The river also has a daily variation, being lowest about three o'clock A.M., and highest in the evening. The flow is also cut off temporarily at times by big snow slides which close the stream until it can melt through.

The highest water is in early July, when the first hot days in this region bring down all the snow from the immediate foot hills. No measure was secured of this flood stage. A 30′ log dam, a penstock 18′ high x 6′ square, and 400′ of 4′x5′ flume with sand box and screens were erected in the winter during the lowest stage of water. Ten feet of the penstock was built of 2″x6″ plank laid flatwise in tar and spiked together; upper 8′ of 2″x4″. Four 1″ anchor bolts extended through the entire height. The pipe line was 1400 feet long and 30 inches in diameter and made of No. 14 B & S steel. These plates as received were 36″x96″, and weighed from 65 to 70 lbs. each. These were punched, rolled and riveted and six sheets put together, the horizontal seams being double, and the vertical ones single riveted and making sections 17½ feet long. These sections were then dipped in a hot bath of maltha and coal tar and thoroughly coated inside and out. Ten barrels of the compound were required for the job. After drying they were hauled to the grade and put together as follows: beginning at the wheel end the sections were united by a 6-inch telescope joint. The larger ends of the sections were expanded by sprinkling with gasoline oil and firing. This process also softened the compound and aided in making a tight joint. The sections were forced together by using a set of triple blocks on each side, having two men operating each set of blocks and a fifth man to guide the end of the pipe and at the same time jar it to a tight fit by using

a sledge against a block of wood on the end of the pipe. As the line was straight, and the fall not over 75 feet, this style of joint proved very effective. The wheel opening being 24″, a reducing section was necessary at this end. A 14″ manhole and a hose connection was also placed in this section. The connection at the penstock was enlarged from 30 to 36 inches to allow an easy entrance for the water.

A 3-inch air valve was inserted in the pipe on the highest vertical bend. Most of the pipe was laid on an elevated grade. It crossed the stream from which the water was taken, and required two special bridges for this transfer. Practically the whole of the pipe was therefore subject to the extreme changes of temperature. Such a pipe should be kept full of water to prevent undue expansion and contraction. If not, there will be excessive leakage.

The building erected to house the machinery was a two-story frame structure 30′x32′, the second story being used as a residence for the operator. The plan was made to accommodate duplicate generators to be operated by a 20-inch double discharge Leffel turbine with horizontal shaft and friction clutch pulleys, 28″ diameter x 13″ face, one for each unit. The turbine with its two 12″x4′ draft tubes was set on foundations as directed by the makers.

The foundations for machinery and building were made of rock and cement. However, the "I" beams composing the longitudinal part of the frame were deflected sidewise by the water pressure, and it became necessary to bring them into line again by the use of jack-screws, and then to extend the concrete foundation to the top of the beams. The wheel was fitted with a Wood governor, which worked very well for small variations of load; but for large ones like that caused by the starting of a compressor, it was of no value in this plant. When such changes were to be made, the operator was notified by telephone, and hand regulation was applied to the wheel. Without this hand regulation, the incandescent lights would be destroyed when a heavy load was thrown off. The plant was operated continuously.

The switchboard was made of kiln dried maple, and arranged for the duplicate 60 K.W. 500-volt compound generators.

The line extended over a very rough section of country, and was rather difficult both to locate and to construct. There were several zigzags so as to cross the cliffs where it was possible for

men to approach the route. Trees were used for poles wherever possible. Other poles were cut from the nearest timber, and rolled or dragged into position, and set in holes blasted from the rock by the use of dynamite. Heavy guys and double cross-arms were frequently used along the line. The wire, 000 B & S bare copper, was received on wooden spools in lengths of 1000 ft. (500 lbs.). It was desired to take about one-th rd of these coils to the mine and run them out from that end. As 500 lbs. was too heavy for one mule to carry, and as it was preferable not to cut the wire, they were transported as followed: The wooden spools were removed from the wire, and the coils separated into four parts with connecting links. Two of these were placed on the pack saddle of one mule, one on each side, so as to balance. The other two were similarly placed on a second mule, the animals being connected by the 10 or 15 ft. of wire between the two loads. The outfit could then move single file up the trail. At the mine the four sections were replaced on the spools, which served as reels when placed on a spindle anchored to a tree. The end of the wire was passed through a friction clutch made of two pieces of plank bolted together, and then guided down the route of the poles by several men. A second section was then spliced and soldered to the first, and the operation continued until 3000 ft. of wire was drawn out, 1500 ft. on each side. Other sections were then drawn out by men and horses from various locations along the route, which could be most easily reached, for the total length of 4400 ft. The completed joints were made Western Union style and soldered by pouring the molten solder over them. The wire was laid up and drawn into position in the usual manner. Special railway insulators were used to anchor the wire on the tops of high bluffs. Care should be taken in such rough country to set the cross-arms on the poles so that the grooves of the insulators will be in line with the wire, also that such construction be made extra good and strong.

The mine consisted of a series of tunnels opening in the face of quartzite ledges on the mountain side at an elevation of about 9500 ft. These tunnels were connected by a network of excavations from which ore had been taken. The tunnels were of irregular size, varying from that of a rectangle less than 4″x6″ to very large rooms or cavities. The mine was practically dry, though some water accumulated in two or three places.

The mine equipment besides incandescent lights in the tunnels and buildings was as follows: one 12″x12″ high altitude type of Norwalk compressor, a No. 4½ Baker blower, and a Lidgerwood hoist. The machines were housed in good sized rooms made of boards and corrugated iron. It is necessary to cover such machines with a tight and strong roof to prevent small pieces of rock from dropping into the working parts. A substantial room for each machine is advisable, which can be locked to prevent meddling by employes other than the ones directly in charge.

The compressor was set in an offset from the main tunnel about 1000 feet from the entrance, and near the work to be done. This method of location is important, as it saves power, cost of installation, and avoids loss by leakage of pipes. No. 0 B & S insulated wire was used in this tunnel. The compressor was operated by a 35 K.W. shunt motor geared on the same bed plate. The air receiver 30″ in diameter x 10′, was located about 20 feet from the compressor. The jackets of the air cylinders and the intercooler were supplied with water from two 735 gallon tanks located about 100 feet from the compressor. A centrifugal pump was driven by belt from the intermediate shaft of the machine, and forced the circulation of the water through suitable piping. From 10 to 18 gallons of water per minute were passed through the compressor, and kept it in fair condition. The speed of the compressor varied from 150 to 200 revolutions per minute, and when operating two Ingersoll-Sargent drills and furnishing blast for one forge at a pressure from 60 to 80 lbs., the motor required from 65 to 80 amperes at 450 to 475 volts.

The No. 4½ Baker blower was located about 200 feet in the tunnel in the "Y" formed by a branch. A 15″ galvanized iron pipe extended from the blower to near the head workings. The blower was operated by a 6 K.W. shunt motor arranged with a reversing switch so that the smoke could be exhausted directly from the head of the mine without scattering it through the other tunnels. Also by this method fresh air could be sent directly to the miners, and the work carried on with the least interruption possible. The blower required 7 to 10 amperes at 475 volts.

The hoist was set up in a branch from the extreme inner end of the main tunnel some 300 feet from the compressor. It was of the Lidgerwood style, operated by a 25 K.W. series street car motor controlled in the same manner. It was arranged with a

drum for 600 feet of $\frac{3}{8}''$ wire rope in one layer. The shop test of the motor showed 1300 lbs. raised 600 feet per minute. The normal load was 700 lbs. at 600 feet per minute.

The wire in the tunnels was of heavy weather proof insulation tied to heavy porcelain insulators bolted to wooden pins which were driven into holes drilled in the quartzite roof and walls. The location of the holes for the insulator supports so as to have the wire clear all obstructions, was done by two men, each with a lighted candle. By holding a candle at one pin and the other a few feet ahead at such points as allowed the lights to be seen by both men, the proper places for the pins were rapidly located. There was a heavy condensation of moisture on the insulators and wire. This was effectively prevented by coating them with P & B paint.

One of the greatest troubles experienced in the operation of high altitude electrical plants is from lightning. Electrical storms are of very frequent occurrence, heavy discharges from the lines occurring sometimes during clear weather. The arresters used on this plant were of the General Electric Co. magnetic blow-out type. Four were placed at the mine, and two at the station. As the mine was a dry one, it was difficult to get a suitable ground at that end. A good sized basin was blasted out of the quartzite near the mouth of the tunnel, and this was filled with charcoal, and the arresters grounded to a copper plate placed in it. The basin was kept damp by water occasionally thrown in it.

The transportation of the station materials and machinery was done by wagons in the usual manner. But that for the mine had to be taken over a very steep, crooked and more or less dangerous trail. All apparatus had to be entirely dismantled. The small parts and attachments were packed in ore sacks and carried on burros. The next larger sizes such as bearings, small gears, pulleys, etc., were wrapped in sacks and loaded on mules. All pieces too heavy for mules or of such shape that they could not be balanced on the pack saddles, were moved on sleds. These sleds were made of $2'' \times 4''$ pine, from three to eight feet long, and having a width of 20 inches. A sled was used for each of the pieces such as armatures, fields, pole pieces, sections of bed plates, gears, cylinders, air receiver, etc., etc. Some of these pieces required the use of four horses in tandem to move them on the trail. In passing the zigzags, blocks and ropes with two

horses pulling down hill, was found to be the most secure and rapid method. Several of the parts of the equipment required the use of four horses, three men and a good supply of tackle, crowbars, etc., about five days to move each one to the mine from the railway station, a distance of about two and a half miles. Only a few pieces received scratches and bruises, and only one piece jumped the trail, and this fortunately did not receive serious damage.

A rough test was made of the station. While not strictly accurate, it may be of some value in planning such installations.

When the output of the generator was 85 amperes at 575 volts, the average velocity of the water in the tail race was 188 feet per minute. The tail race 6′ 7½″ wide, x 4′ deep, x 150′ long, was made of planks, and had a fall of $\frac{3}{16}$″ per foot. The water velocity as given was obtained by counting the time for light floats to travel about three-quarters of the length of the race. These floats were placed in the middle, and in various parts of the surface of the stream. The depth of the water for this load was from 9¾ to 10 inches.

The approximate cu. ft. per min. was then as follows:

$$\frac{79\frac{1}{2} \times 10 \times 188}{144} = 1033.$$

Elevation of standing water in the penstock 103′ above datum.
" " " lower end of draft tubes 26.2′.
Total head = 103 — 26.2 = 76.8′.
Friction loss in 30-in. pipe for 1037 cu. ft. per min. = 4.3′.
Effective head = 76.8 — 4.3 = 72.5′.

$$\text{H. P. of water} = \frac{1033 \times 62\frac{1}{2} \times 72.5}{1033} = 142.$$

$$\text{Electrical H. P. output} = \frac{85 \times 575}{746} = 65.5.$$

Velocity of water in tail race for friction of station plus 40 — 20 C. P. 3.6 watt lamps was 88.8′ per min., the depth 4″ = 19.6 cu. ft. per min.

H. P. of water for friction plus the 40 lamps =

$$\frac{19.6 \times 72\frac{1}{2} \times 62\frac{1}{2}}{330000} = 26.9.$$

A diamond drill outfit for the San Bernardo silver mine of San Bernardo, Colorado, presents an example of construction

work where it was necessary to transport the machinery and materials over a wire rope tramway. The plant was also installed in midwinter when the country was buried in snow, many of the gulches being filled, and the tops of large trees covered from sight. The source of power is Trout Lake, a pretty pool of water near the summit of the range. The same source also furnished power for the Telluride high tension long distance transmission plant which has been described in the TRANSACTIONS[1]. A 6 K.W. 250-volt generator was installed in the concentrating mill and belted through a countershaft to one of the two turbine wheels which operated the mill. The wheels had no regulators, but operated the generator at near enough constant speed for all practical purposes for the work when the whole mill was running. But when operating the generator alone, the wheel was constantly racing with the change of load, and regulation was necessary, which was had by putting a friction brake on the shaft of the wheel to be operated by a hand lever.

The required 2500 feet of line was erected in most part on the towers of the tramway. That in the tunnel was fastened on porcelain insulators bolted to the framing timbers.

It was desired that no piece of the machinery should weigh over 250 lbs., but the designer did not entirely comply with this request. Fortunately no damage was caused by the extra weight of some pieces. The drill had to be entirely dismantled, and the parts packed in ore buckets, and dropped at the nearest point to the tunnel opening. From here they were rolled and dragged through the snow to the tunnel. The machine was set up for work some 740 feet within the tunnel. It is the testimony of those who have tried it, that there is some difference between the ease with which a complicated machine can be set up in a wet tunnel, and in the assembly room as conveniently arranged in the factory.

The drill was of 600 feet capacity, and its total weight with the rods about 5000 lbs. The dimensions were as follows: Length 9′, width 4′, height 6½′. The drill rod was operated by a 2 K.W. shunt motor, which required from 6 to 8 amperes at 240 volts for normal operation, and 10 to 12 amperes when choked up. A 2½″x4″ Gould triplex plunger pump furnished water under 40 to 60 lbs. pressure to the drill, this motor re-

1 TRANSACTIONS, vol. ix, 1892, p. 430.

quiring about 10 amperes. The drill rods were $1\frac{5}{8}''$ outside diameter and for $\frac{3}{4}''$ core, and made in 8′ sections. The outfit was furnished with two bits set with eight 2-carat stones each, and with five blanks. The machine drilled from 7 to 10 feet per day of eight hours operation, and required a newly set bit each day.

As a representative plant reached by a wagon road, that of the New York and Chance mines of Creed, Colorado, may be given. This was not so difficult in some respects to construct as the one for the American Nettie mine. All the machinery was transported on wagons over a road constructed at great expense for the mining district. The power station is a frame building located on West Willow creek in the cañon behind Bachelor mountain about $1\frac{1}{2}$ miles from Creed. This town consists of a few frame buildings, the whole outfit appearing as if it had been driven like a wedge into the cañon until the two rows of houses had become so squeezed (the town was built under pressure) that they had to climb the mountain sides in order to leave a little space between them for the entrance of pack trains and the inhabitants. Amethyst is located a mile farther down, and has more room. The plat of the two towns resembles a fan, Creed being the handle.

The cañon begins an abrupt ascent at the base of Bachelor mountain, and the wagon road follows a steep and zigzag course to the mines, which are in the timber land near the top. Log foundations were used for the building and machinery. The equipment consisted of a 5′ Pelton wheel with two nozzles, 4″ shafting, and necessary pulleys to drive two generators. The governor was of the differential type operated by a small water motor. One multiplier 100 K.W. 500-volt direct current generator was installed with the necessary switchboard. The line, 5700 feet, was of 00 B & S wire with tree insulation. It followed a deep gulch and thence over a high and rocky cliff and across the timber lands above to an air shaft over one of the tunnels. At this point a Siemens lead-covered cable of 240,000 circular mils was attached and led down the shaft and through the tunnel 400 feet to a hoist. A compressor was located along the line about half way between the power house and the mine. For lightning protection there were the magnetic blow-out arresters at the station, and a strand of barbed wire on the tops of the poles the entire length of the line. This wire was grounded frequently to

the water pipe and to plates set in the ground. The Rand compressor was driven by a 45 K.W. shunt motor belted to it. The hoist was equipped with a 35 H. P series motor with street car control. Such hoists are designed after the usual plans which have been approved in the construction of those operated by steam.

The dam was made of 6″x 6″ sawed timber about 30′ long x10′ high, x6′ broad, the front and back being laid solid, the two parts joined by braces, and the space between filled with earth. The bottom was started in a trench cut in the rock, and the timber work filled with concrete for the first few feet. A plank spillway 2′x10″ wide, x 8½′ long, x 18″ deep, carried the water to the penstock. The water pipe was of black iron, the upper half 22″ and the lower 16″ diameter. The total length of 2300 feet was made up of four different weights of iron. That at the wheel was No. 8 B. & S., the remaining fourths of 10, 12, and 14 B. & S. respectively. The 24′ sections complete with horizontal seams, double and vertical single riveted, bolted flanges, gaskets, etc., were shipped from Denver. The total head was 325 feet, and the effective pressure when operating was 145 lbs. per inch. The plant could only be used part of the year, as the stream was generally dry during the summer.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, November 23, 1900.

The 148th Meeting was held this date at 12 West 31st Street, and was called to order at 8:20 P.M. by President Carl Hering.

THE SECRETARY:—At the meeting of the Executive Committee this afternoon the following Associate Members were elected:

Name.	Address.	Endorsed by.
BALDWIN, GEORGE PORTER	Sales Agent, John Martin & Co., 31–33 New Montgomery St., residence, 1806 Larkin St., San Francisco, Cal.	John Martin. F. V. T. Lee. T. E. Theberath.
BALLOU, WARREN JAMES	Electrician, Woonsocket Elec. Machine & Power Co., Station No. 2, Woonsocket, R. I.	Tom H. Gregg. H. A. Storrs. Harry D. Reed.
CONVERSE, V. G.	Engineer and Manufacturer, 3rd Street and Penn Ave. Pittsburgh, Pa.	P. N. Nunn. Chas. F. Scott. R. D. Mershon.
CHATELAIN, MIKAIL ANDREJEVITCH DE	Prof. of Electrical Engineering, Mining Institution and Electro technical Institution, Wasily Ostrow, 10 Line No. 5, St. Petersburg, Russia.	Carl Hering. R. W. Pope. C. O. Mailloux.
DEEDS, EDWARD ANDREW	Head of Engineering Department National Cash Register Co., Dayton, O.	G. D. Shepardson. E. P. Roberts. F. B. Corey.
HAVER, GEORGE JR.	Gen. Supt. and Elec. Eng. Cincinnati Gas Co., Elect. Dept., Cincinnati, O.	Joseph Sachs. Bert L. Baldwin. C. Stowe Reno.
KELSEY, JAMES CEZANNE	Switchboard Trouble Mgr. N. W. Telephone Exchange Co., Minneapolis, Minn.	John. J. Carty. G. D. Shepardson. Chas. L. Pillsbury.
LEYDEN, HARRY RUSSELL	Mgr. Hamilton Elec. Lt. & Cataract Pr. Co., Hamilton, Ont.	C. C. Chesney. W. F. White. R. W. Pope.

LOWTHER, CHRISTOPHER MEYER	Sales Engineer Crocker-Wheeler Co., New York; res., 168 Arlington Ave., East Orange, N. J.	F. V. Henshaw. Gano S. Dunn. E. M. Archibald.
SETHMAN, GEORGE HENRY	Mechanical and Electrical Engineer, Skinner & Sethman, 2243 Irving St., Denver, Colo.	J. W. Stearns. C. E. Doolittle. Lewis Searing.
SPRINGER, FRANK W.,	Assistant Professor Electric Engineering, University of Minn., Minneapolis, Minn.	G. D. Shepardson. John J. Flather. Chas. L. Pillsbury.
STERN, PHILIP KOSSUTH	Practicing Electrical and Mechanical Engineering, 130 Fulton St., N. Y.	T. C. Martin. Fred A. LaRoche. Ralph W. Pope.
SNYDER, NATHANIEL MARION	County Surveyor for Scotts Bluff Co., Gering, Nebraska.	Ralph W. Pope. C. O. Mailloux. Saml. Sheldon.
WALKEM, GEORGE ALEXANDER	Electrical and Mechanical Engineer, P. O. Box 595 Vancouver, B. C.	Louis A. Herdt. Ralph W. Pope. K. G. Dunn.
WOODWORTH, LEON BYRON	Electrical Engineer, New Heriot Gold Mining Co., Johannesburg, Transvaal.	J. W. Kirkland. M. A. Oudin. W. L. R. Emmet.

Total, 15.

The following Associate Members were transferred to membership:

Approved by Board of Examiners, October 12, 1900.

W. A. LAYMAN,	Assistant Manager and Treasurer, Wagner Electric M'f'g. Co., 2017 Locust St., St. Louis, Mo.
FERD. SCHWEDTMANN,	General Superintendent, Wagner Electric M'f'g Co., 2017 Locust St., St. Louis, Mo.
LOUIS J. B. WALL,	Full Partner, Splatt, Wall & Co., Perth, Western Australia.

Gentlemen, last spring a bill was introduced in the National Congress looking to the establishment of a standardizing bureau in connection with the Bureau of Weights and Measures in Washington. The Council appointed a special committee to take action in regard to this matter and use what influence we had in carrying the measure through. Congress adjourned before any action was taken, although a Congressional Committee reported favorably upon it. It is now about to be taken up again, and in accordance with the recommendation of the Chairman of our Committee a resolution has been prepared to be brought before the INSTITUTE to-night which, it is supposed, will have some effect in aiding arguments in favor of this measure. And I wish to assure you, before this matter is brought up, that it has received the earnest consideration of the Council and the Committee, and you will remember in September last Prof. Carhart read a paper in which he gave arguments in favor of it, so that the INSTITUTE is already committed in favor of doing what can be done toward the passage of the bill.

THE PRESIDENT:—Dr. Sheldon has a draft of resolutions which are to be offered at this meeting.

DR. SAMUEL SHELDON:—Mr. President, the Committee has adopted this form:

WHEREAS, bills "to establish the National Standardizing Bureau" were introduced in the Senate and in the House of Representatives, numbered and dated S. 4590, May 14, 1900, and H. R. 11350, May 5, 1900, respectively;

WHEREAS, the purpose of the said bills is to provide for establishing and operating a bureau for the construction, custody and comparison of standards used in scientific and technical work, the testing and calibration of apparatus and the determination of physical constants, and the properties of materials;

WHEREAS, the necessity of such a bureau is universally recognized:

WHEREAS, such bureaux have already been established in several European countries, and are being established in others;

It is resolved that we, the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, in meeting assembled, this 23d day of November, 1900, strongly endorse those bills and recommend their passage by Congress.

The resolutions were adopted as read.

THE PRESIDENT:—The next thing in order is the paper by Mr. Behrend on "The Mechanical Forces in Dynamos Caused by Magnetic Attraction."

[See p. 599, November, 1900, issue.]

Discussion.

The President:—Mr. Behrend has developed in this paper a most interesting formula, and one which is extremely simple. It is for making a calculation which formerly was very difficult to make, and one which is of special importance with induction motors where the air-gaps are so extremely small. The Oerlikon Company, I understand, have a rule to make the air gaps of such motors one-tenth of one per cent. of the diameter of the moving part, that is, one one-thousandth of the diameter. In such cases these forces become very important. The paper is open for discussion.

Mr. Gano S. Dunn:—I welcome the development of a formula of this kind, because it will very materially help in those operations of designing in which magnetic pulls have to be calculated; and while in direct current designing the matter is not of such great importance as it is in alternating current, where, on account of the necessity of high frequency, the polar construction has to be forced, yet it is customary now in specifications for direct current generators to call for the amount of unbalanced pull that will occur on an armature for a given eccentricity. This, that the strains on the engine shaft may be properly calculated.

The bringing up of this subject calls attention to a feature of design on which I have always had strong convictions—namely, the size of air-gaps. You have just mentioned that the gaps of the Oerlikon Company are figured at one-tenth of one per cent. of the diameter for induction motors—and it is well known that the gaps used in induction motors and by many builders of direct current machinery are extremely small. I think this is wrong and contrary to the best mechanical engineering practice. To my mind one of the great disadvantages of the induction motor, one of the disadvantages from which it must be freed if it is to take its proper place in the distribution of power, is this small air-gap. The machines with which I have had to do have always been characterized by large air-gaps so as to avoid the trouble which has caused the presentation of Mr. Behrend's paper. I consider that for a machine whose armature is five feet in diameter the air-gap should be half an inch. This large air-gap makes displacement of the armature from its center relatively unimportant Were the gap three-sixteenths of an inch, as it is frequently made, an eccentricity of the armature of a thirty-second of an inch, which is not uncommon, from the wear of bearings or the settling of foundations, would make a very serious distortion or perturbation in the distribution of the flux from the poles, since it is one-sixth of the total gap; whereas, such distortion or perturbation is practically insignificant if the gap is as large as I have said.

With regard to the stresses in induction motors I should like to ask, as a matter of information, whether it is a fact that when

an induction motor is running, and has a certain amount of eccentricity in its armature, there is an unbalanced pull between the armature and the stator resulting from that eccentricity. I have always believed so; but in discussing this question with a member of the INSTITUTE at its general meeting in May, a man who is very well posted, he assured me that while such a phenomenon took place in direct current machines, in synchronous motors and that character of apparatus, it was entirely absent in induction motors. If the facts could be brought out in the discussion here I think it would be very useful. I am sure that the formula of Mr. Behrend will help us to determine these strains resulting from eccentricity much more readily than we have been able to determine them before, when we have had to figure them on a trial and error method.

MR. C. O. MAILLOUX:—The effect of displacement of an armature in a magnetic field is not to be neglected, even in the case of direct current machines, especially when they are of large size. It may happen that in some cases when the field becomes fully excited there will result from the difference of magnetic pull exerted by the different poles a component which may tend either to increase the apparent weight of the armature or to decrease it. This effect is of special importance when it is attempted to determine the efficiency of a dynamo, for instance, by the so-called indicator method. I have had some very amusing experiences in that connection which incidentally illustrate the entire uselessness of the indicator method as a means of determining the efficiency of a dynamo. I have seen cases (in units of 150 to 250 K.W. connected direct to slow speed engines) where the vertical component due to armature weight apparently, changed when the load came on; that is to say, the pull exerted on the bearings was not the same when it was running light, as when it was running loaded. This is particularly apt to be the case with dynamos whose armatures have several "paths" in parallel, especially when the brushes are not set in such a manner as to give absolute E.M.F. balance, or if the poles themselves are not thoroughly balanced, that is to say, if the different magnetic circuits have unequal fluxes. I have seen cases where one obtained some interesting results, if one took indicator cards of the unit when running without external load, that is to say, when running with only the field excitation, or even without the excitation (more especially in the latter case), and then undertook to use this "load" as the constant (representing various losses), to be subtracted from the indicator results for the total load carried, when the unit ran fully loaded. I have seen the efficiency come out as a hundred and one or two per cent. This is simply due to the fact that after the load came on, the armature was apparently lifted and its friction load seemed to have decreased instead of increasing. Hence, on deducting from the total indicated load the "loss load" obtained when the engine ran light, the differ-

ence (representing the "power applied to the dynamos," for generating the external or useful output of electrical energy), is smaller than it ought to be, and the efficiency comes out apparently high. The error would perhaps not be suspected excepting in cases where the percentage obtained is unexpectedly high, or where one may be able to account otherwise for the discrepancy in efficiency. The phenomenon first came to my attention in some cases where I knew that I could, by the "method of losses," account for seven or eight or more per cent. of loss in the generator set, and, when I found that, by the indicator method, the loss was apparently only one or two per cent., I immediately suspected that there was something wrong. This trouble occurs even with machines having large air-gaps, and it is one which should be carefully considered, not only with reference to the efficiency of the machine when operated under full load, but also on account of other troubles to which it gives rise.

I should also have added that when the displacement of the field is of the opposite kind, a contrary result may be expected and is often found—namely, instead of the efficiency being greatly increased, it is very much reduced. In such cases it is to be presumed that the vertical or weight component, instead of being decreased as the load comes on, is considerably increased thereby, and consequently the friction load is also increased, while the load is turned on. I ought to state that these observations were made by me some years ago, before the "method of losses" (now the only method endorsed by the A. I. E. E.) had superseded the indicator method.

Mr. Behrend:—May I shortly answer the two speakers? First, I should like to make a few remarks about what was brought forth just now about the efficiency of dynamos being lowered by an eccentricity of the armature. Now I understood you that it is not always necessary to have an eccentricity causing magnetic strains in order to get a lower efficiency than the one that might be calculated from certain data that you have. Well, I think there is an explanation of this. Most high speed dynamos are not very well balanced; that is to say, I mean the rotating part is not very well balanced; it often has a heavy point. Now a heavy point causes a perfectly astounding amount of waste of energy. You can easily make an experiment on this by simply taking a fly-wheel and putting a bolt into the rim on one side, running it with an electric motor and measuring the power, and then balancing the wheel perfectly, and measuring the power again. The loss of energy is perfectly surprising. It need, therefore, not necessarily be an eccentricity and a negative pull consequent on that, but simply a mechanical defect of the armature perfectly sufficient to explain a certain increase in the losses.

As to Mr. Dunn, the first speaker, I wish to say that of course it offends the feeling of a mechanical engineer if he has to decrease his air-gap very much; but in some cases he simply *has*

to do it, because if your poles get close together, and they always do if you have to build large dynamos for high frequencies or slow speeds, in order to avoid getting tremendous diameters which you cannot deal with. Therefore you have to lower your air-gap in order to avoid too much leakage. But I am indebted to the speaker for having brought forth this point.

As to the mechanical pull in induction motors I wish to make a statement which, however, I ask not to take down, because I have not carefully thought about the matter.

MR. MAILLOUX:—I wish to state for the information of Mr. Behrend that the particular dynamos in which I noticed the phenomena referred to in the most striking degree, were not driven by high speed engines. They were slow speed engines of the Corliss type, in which the shaft diameter of the 250 K.W. unit was 18 inches at the middle and 15¼ inches at the main bearings, the design, material and workmanship being certainly of the very highest grade that can be produced in this country. I do not believe, therefore, that any of the disturbances which he refers to could possibly, in the cases referred to by me, have acted as a source of error or as a cause of discrepancy in the results.

MR. HENRY FLOY:—I would like to support Mr. Behrend's theory with regard to the induction motors. I know from practical experience in some cases that have come to my notice, that if the rotating part is a little out of the center, the magnetic influence has been enough to bend the shaft to such an extent as to pull the rotating part right up against the stator and prevent its rotating at all.

MR. BEHREND:—I merely wish to say that my remarks about the decrease of efficiency do not apply to the case brought forth by the speaker. I mean that if you have to deal with slow speed engines, then the effect of a poorly balanced armature is not so serious. I did not know that the dynamos that the speakers mentioned were slow speed dynamos.

MR. DUNN:—I think that perhaps one reason why designers of electrical machinery have been tempted to use such small air-gaps as have been used, has been because they have not realized that such tremendous strains are introduced into the machine by the unbalancing that takes place. If Mr. Behrend's formula, by making calculations of these strains very much more simple than has heretofore been possible, shall divert us from small air-gaps, I think it will lead us to accomplish a great deal in a very useful work.

MR. C. O. C. BILLBERG.—I beg to call the speaker's attention to the fact that in alternating current machinery we are dealing with such a low magnetic density that we cannot afford to have a large air-gap. In direct current machinery we may use from 16,000 to 17,000 lines of force per square centimetre, but in alternating current machinery we have to limit ourselves to from 2,000 to 5,000.

MR. DUNN:—I was not speaking solely from the point of view of direct current machinery, and I realize the sacrifice that would have to be made to get these large air-gaps in induction motors. But I wish to make the point that I think the sacrifice worth making. What does it avail us to have a comparatively low power factor if the machine is going to give us any trouble whatever mechanically? I consider that mechanical performance is the very first requisite, and that we ought to sacrifice other things to get it, even air-gaps.

THE PRESIDENT:—I would like to ask Mr. Behrend, who is quite familiar with the design of induction motors, whether it is not a fact that the size of the air-gap is of much more importance in induction motors than in continuous current motors, and would not the sacrifices by making the air-gap large in induction motors, be much greater than they would be in continuous current motors?

MR. BEHREND:—I think it is hardly possible to build induction motors with large air-gaps owing to the tremendous exciting currents, or no load currents, produced by a large clearance; your motor would be electrically so poor as not to be utilizable at all.

As to the densities in generators I wish to say that of course 3,000 per square centimetre is by no means the upper limit. It is the upper limit if you have to deal with frequencies between 60 and 80, but if you can work at frequencies of 42 to 50, you may, I think, safely adopt inductions between 6000 and 7500. In inductor generators the frequency is, loosely speaking, only one-half; as far as the losses through hysteresis and eddy currents are concerned. Therefore the inductions in these machines may be about 10,000 or 12,000 in the air-gap; 12,000 is by no means an outrageous induction adopted for inductor machines of a frequency of 50.

MR. FREDERICK V. HENSHAW:—One of the recent speakers I understood to explain the necessity for a short air-gap in an induction motor as being due to the fact that the density in the air-gap was very small, and it seems to me that point requires a little clearing up. If the density is very small, then I should think they could use large air-gaps. If the density was very great why then small air-gaps would be in order.

MR. BILLBERG:—I was speaking about the induction in the iron, the density in the air-gap will be smaller yet. It is not a question of using a small density, it is a question of the cost of getting the magnetic lines of force through the air-gap.

MR. HENSHAW:—My point was that if the density was very high, it would cost so much more. The fact that the density is low and the air-gap small, is the only thing that makes the induction motor commercially possible at all.

DR. SHELDON:—I am not sure whether I know anything about this or not. But the Edison Illuminating Company of Brooklyn has issued a little pamphlet to people who intend attaching in-

duction motors to its three-phase circuits, which says that induction motors of certain sizes, which are to be attached to its circuits, shall not have a starting current of more than twice the normal, full-load working current. Now, if the air-gap is large, I believe that the starting current is quite large. And if the air-gap is small the starting current is not necessarily large. The cause of the former is magnetic leakage. There are lines which do not link between the stator and the rotor. Some of the lines which are produced by the current in the primary, encounter the large reluctance in the air-gap and leak around back home again without having linked with the windings in the secondary. Therefore it is necessary, in order that a motor shall start satisfactorily, to have a small air-gap.

[Communicated after the Meeting by Dr. A. E. Kennelly.]

The paper under consideration conveys two main propositions, namely:

1st. That if a dynamo armature instead of being round, had a square contour, and were symmetrically located within a symmetrically slightly larger square field-polar cavity, and a constant magnetic difference of potential maintained between the opposing parallel plane surfaces of field and armature, so that the flux density in the air-gap should be inversely proportional to the thickness of the said air-gap; then if one of the faces of the square armature be displaced parallel to itself through a small distance Δ, the total resultant magnet pull upon the square due to the unbalanced magnetic forces on the sides having respectively a reduced and increased air-gap is $\frac{S\mathfrak{B}^2}{8\pi} \cdot \frac{4\Delta}{\delta}$ dynes, the surface δ being in this formula the surface of one of the sides of the square armature.

2d. The proposition contained in the paper for the case of a round armature is virtually equivalent to resolving the round armature into a square armature of the same breadth, and of a hypothetical perimeter equal to the actual circumference. The displacement of the armature takes place parallel to one of its sides through the distance Δ as before. The total resultant magnetic force acting upon the real circular armature will be the same as the computed force acting upon the ideal square armature.

Consequently the two propositions in the paper actually resolve into a single proposition on the hypothesis that a round armature is reduced hypothetically to a square armature of equal perimeter.

In the case of multipolar continuous-current generators, except where the air-gap is very small relatively to the dimensions of the machine, the resultant magnetic forces are usually not so

serious as the dissymmetry of electromotive forces produced. In multipolar machines the eccentricity of the rotor may produce marked unbalancing of the electromotive forces in the segments of the armature, unless special precautions are taken to prevent this.

It is interesting to notice that the agreement between the formula and the first observation reported in the paper is so good, although the second observation, when the rotor was in contact with the stator, was not so good. Manifestly, however, in the latter case a constant difference of potential between the two sides of the air-gap could not be maintained, and the result would be vitiated by this cause alone, so that close agreement could not be expected.

[Reply by the Author.]

In reply to Dr. A. E. Kennelly's interesting communication, I wish to say that it is perfectly true that the second case treated in my paper may be reduced to the first by assuming an ideal square armature in a square field having the same perimeter as the circular armature in the circular field, but Dr. Kennelly doubtless arrived at this interesting way of putting the results of my paper by contemplating the formulas, and I do not see at present how his comparison could be reached by a short cut. I entertain no doubt, however, that a simple graphical solution is possible.

As far as I am acquainted with dynamo-design, I believe that the winding of the armatures of large multipolar machines built by cautious engineers is always such as to neutralize the inequalities of the electromotive forces in the various segments. Eccentricities, though small, are unavoidable, and the winding known as that of Arnold, the device of Lammet, Mordey's connections, they all have been invented to meet the difficulties mentioned by Dr. Kennelly. The last-mentioned has been adopted by the Oerlikon works in their large 900 H. P. direct current generators at Rheinfelden; machines that had to be built with 32 poles for 55 R.P.M. and 8000 amperes.

Discussion.

[See p. 576, November, 1900, issue.]

Mr. Floy:—I would like to add a few remarks to what has been said in regard to these curves of charging current. There was a tendency shown, from the points as plotted, for the curves to sag below zero at the lower end. The instruments that were used being designed especially for high voltage and large current readings did not read closely below 10,000 volts with the voltmeter, or 1 or $1\frac{1}{2}$ amperes, with the ammeter. The result was that we could not get any satisfactory readings down at the lower end of the curves, although some curves, as I have stated, showed a tendency to sag at the lower end. To-day I received a letter from Mr. Edward P. Burch, of Minneapolis, who was formerly superintendent of the Twin Cities Street Railway. Mr. Burch

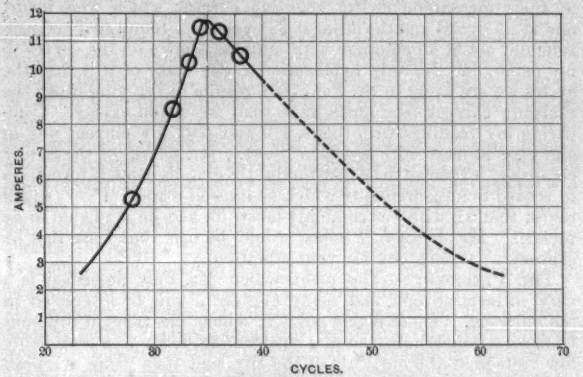


Fig. 17.

took some measurements on paper cables furnished by the National company for supplying current from Minneapolis to St. Paul in connection with the St. Anthony's Falls Water Power Company. These cables are respectively seven and nine miles long, and have been in use about three years. They transmit three-phase current at 12,000 volts potential. Mr. Burch said that he noticed in the measurements that he had made, that instead of the charging current increasing directly as the voltage, there was a tendency for the lower end of the curve down near the zero to sag below what would be theoretically expected. This conclusion would agree with what I observed. Later I hope to have other instruments at St. Paul to make measurements on the lower part of the curves which results I shall be glad to publish later if we develop anything of interest. Mr. Burch also said that he had made some measurements on his cables by maintain-

ing the voltage constant and varying the number of cycles. All my measurements were made at 60 cycles. Mr. Burch's readings I plotted this afternoon in a rather crude curve, but so that you can all see it. These are the cycles along here [see Fig. 17], and here are the amperes of the charging current on his seven mile cable. As the cycles increase we would naturally expect the charging current would increase in the same proportion; but you will see there is a critical point up here at which the curve seems to bend and come down. Mr. Burch's measurements did not go below this point; but I have drawn the curve showing that the amperes are apparently very materially reduced as we get the cycles up to 60. This is of interest, because it is new, at least to me, and Mr. Burch deserves credit for having demonstrated this phenomenon in his cables. I have talked with the manufacturers of our cables, and they do not seem to have had this point in mind in their measurements for charging current, which were made, one at 25 cycles and the other at 32 cycles. I found that their results did not at all compare with mine as shown on the curves in my paper, and the only explanation I can make of it is that the cycles we are using in St. Paul (60), results in bringing down the charging current very much more than we would expect. Comparing my readings with theirs, I found that my current was in one case at least 50% less than theirs. Mr. Clark, of the Safety company, expected to be here to-night to give us some information in regard to measurements which he himself made. I very much regret that his wife was suddenly taken ill, and he is unable to be present. Mr. Jackson, I hoped would be here, but I see that he is absent. I thank you for your attention.

THE PRESIDENT:—The plant which Mr. Floy described is a very interesting one, and many engineers will be interested in the outcome. There is one point in which this plant is different from most others; instead of transforming down to a reasonably low voltage at the outskirts of the city, and then using overhead wires through the city, the current is carried through underground cables, at the original high voltage to the distributing station. This is a new departure from the usual practice, the success of which will be watched with great interest. I do not believe there are many cases in which high voltages are used in underground cables, but I think Mr. Floy is mistaken in saying that this is the first time. There were some cables shown in the Paris exhibition this year which were subjected to 25,000 and even 30,000 volts continuously, and one of them was a paper cable. The fact that one cable in this installation is made with paper and the other with rubber, is also a very interesting feature of the plan, as it will help engineers to find out whether paper will do as well as the more expensive rubber.

I have no doubt there are others besides myself who would like to know why there is a transformation from three-phase to two-phase, instead of distributing at three-phase; also why some of

the current is transformed to continuous current. The paper is open for discussion.

MR. TOWNSEND WOLCOTT:—I would like to ask Mr. Floy if any theory was advanced to account for the falling off of the charging current in the cable at high frequency.

MR. FLOY:—As I say, I just received this letter and have not had much time to think over it myself. For the present I have not any explanation to offer.

MR. WOLCOTT:—It is a well known fact that the apparent electrostatic capacity of a condenser, or a cable, is different with different frequencies. A paper was read by Dr. Pupin not long ago in which that subject was discussed. I think the observed phenomenon might have some relation to this fact; the so-called absorption of dielectrics. With different materials this would be different. That is, the frequency at which the maximum current was taken, should be different for different insulators.

MR. BEHREND:—I have listened with the greatest interest to Mr. Floy's admirable paper. There is one point about which I wanted to make a few remarks. Mr. Burch's curve is the familiar resonance curve which you always observe if you increase your frequency. If you have an inductance and a capacity in the same circuit, as you have in the case of underground cables, and if then you raise your frequency, you observe this peaky curve. The current increases up to a certain frequency and beyond a certain frequency it decreases. This phenomenon is very old. It is simply the electrical analogy to the mechanical phenomenon presented to us by what is called forced vibration. If you have, for instance, a pendulum vibrating, this pendulum has a certain natural period. If you force this pendulum into vibration then you will observe that up to a certain frequency of the driving force, the excursions of the pendulum increase; they increase up to a point which is called the point of resonance. If you increase your frequency beyond this point, the excursions of the pendulum again decrease. This is an old phenomenon. About thirteen or fourteen years ago that same curve was given by the late Prof. Heinrich Hertz in his researches on electro-magnetic waves. In 1890 it was brought up through the discussions of the resonance phenomena observed on the Ferranti cables between Deptford and London. In connection with that I will say that the Ferranti cable is perhaps the oldest high voltage cable ever laid. It was laid, if I remember rightly, ten or twelve years ago, and carries 11,000 volts, and has carried that voltage for the past ten years. Mr. Kapp then gave before the Physical Society of London a lucid explanation of the resonance effect, and I think you will find his explanation in almost any book on alternating current phenomena.

THE SECRETARY:—I have been particularly interested in this paper for the reason that the last paper that was written by my brother, the late Franklin Leonard Pope, and which was read at

the Niagara Falls meeting in 1895, was on the reconstruction of a small plant, where steam power was originally used, and afterwards transmission for about four miles from a water power was substituted. It would be interesting to me, and probably to others, if we could get at the financial reasons which led to this particular change treated by the author to-night; for in the past we have had a great many discussions on the relative cost of water power and steam, and there have been many discussions of the same kind before the American Society of Mechanical Engineers. It has been argued that with a reasonably low price of coal, and using modern steam engines, equal economy could be reached by the use of steam. Some of the mechanical engineers went so far as to say that at Lowell, Massachusetts, for instance, if the water plant had not already been developed and the dam and canal constructed—if the plant was to be put in operation to-day, that they would use steam instead of water power; but having the water power and dam and having invested the money in it, it was cheaper for them to go on, than it was to abandon it. I presume from reading the introduction to this paper that there were good economical reasons for this change, and if it is not the proper time now to give those reasons, I should hope that they might be presented in the future.

The policy of using two kinds of cables, which Mr. Floy brings up, reminds me that several years ago, when I was engaged in the effort of trying to sell underground cables, and one of my customers had begun using something else, that I suggested that he should try more than one kind; for, I told him, it was a question of lapse of time to ascertain whether these cables would endure or not, and if they endured five years and then gave out, and he then tried another kind it might be 25 or 30 years before he found out which was the most serviceable, and I suggested that he lay down some of each kind, including ours, and arrive at the result in the first five years. My argument did not prevail, however, but I am glad to hear that there is somebody else proceeding along that line, and that the author bought all the types of cables he could obtain.

This statement of Mr. Floy's in regard to transmitting power from one city to another enables me to bring up a point that came to my notice abroad last summer that was of considerable interest to me, because I had always supposed that this country had arrived at the acme of protection in various industries. But as we were riding on a line from Geneva to a mountain east of that city, we started on an electric line and changed to a steam dummy which carried us for less than a quarter of a mile to an electric rack railroad up the mountain which was over the boundary line in France. The reason for using this link of steam line was that the French authorities would not permit this electric railroad in France to be operated by a current that was generated by water power in Switzerland.

MR. DUNN:—As competition in mercantile lines is supposed to be the soul of trade, so competition of opinion seems also to be of use. A few weeks ago I had the pleasure of being at Richmond, Virginia, where there is a dam for the purpose of getting power from the James River to the amount of 14,000 H. P., and there they thought there was no dam like a concrete dam. It had been put across the river in a very substantial manner, and the method of anchoring it was extremely interesting. I presume that some day in years to come we shall know in regard to dams as we shall know in regard to insulation—which is the best kind.

The reference to the use of aluminium is interesting, particularly to me. The subject is one that I think will have more attention as time goes on, and the fact that this line could have been built for nearly $4000 less—if built of aluminium instead of copper shows a premium on the construction of aluminium lines which I am sure will soon result in their general introduction.

Prof. Perrine's paper, read before the INSTITUTE at its general meeting in Philadelphia, gave some very interesting particulars about the use of aluminium; in regard, for instance, to the strain it would stand before the sag became too great, and as I remember the paper he also said that owing to the great difficulty of soldering—in fact, there had been no good means yet devised for connecting aluminium lines by soldering—they had twisted the ends of the conductors together without soldering, and experienced no unfavorable results from this method of connecting. There were brought to me to-day some samples of pure aluminium wire which show a new method of making joins, which is a substitute for solder. The process was not revealed, but it consisted in welding the pieces together so thoroughly that you could not tell there had ever been any joint between them. Surely, if aluminium is now to be capable of being welded and connected so thoroughly as this, there is still further reason for its introduction as a conductor.

The value of the figures of nearly $4000, the amount by which it was cheaper to construct an aluminium line over one of copper, would be increased if we could know what the total cost of construction of the line by copper or by aluminium was. In other words, what was the ratio of the cost of the aluminium line to the copper line.

And with regard to the insulation, we are, indeed, in the dark as to how long our insulations are going to last. The whole electrical business is so young that we have not had experience enough to say what will be the behavior of any kind of insulation with the effects of time; whether that insulation be around an underground conductor at high potential, or whether it be lining the slots of a generator. The general opinion seems to be that an insulation, or dielectric strength, follows the same laws

as mechanical strength, in possessing an elastic limit and an ultimate limit. While many an insulation will stand a very high voltage for a comparatively long time, it will not withstand that same voltage indefinitely; but if that voltage be within what may be termed its elastic limit, then it will withstand it indefinitely.

I hope that we may have the privilege a few years from now of hearing again from Mr. Floy on the subject of these cables, to see whether 25,000 volts is within or without the elastic limit of his insulation.

THE PRESIDENT:—The process of welding aluminium that Mr. Dunn spoke of was described in this room a month ago, at least I suppose it is the same one. It consists simply in heating the aluminium to a certain definite temperature at which it has been found that it can be welded very readily with a hammer. The temperature is, I believe, that of a dull red heat, at which the metal becomes slightly soft. The process was on exhibition in Paris this year.

THE SECRETARY:—Was it not understood in regard to aluminnium that it could not be welded? There are several processes in the arts that could not be used for aluminium, and it seems to me that welding was one of them. I should suppose that if it could have been welded that this process would have been found out some years ago in working it.

THE PRESIDENT:—I do not know whether this is a new process or not. I only know that it was exhibited in Paris this year as a new process. I thought, as Mr. Pope did, that it was surprising that it had not been known before. The reason probably is that the temperature to which it must be heated must be a very definite one; when it is above or below, the process is probably not successful; at least that is the way I understood it. The welds on the pieces shown in Paris were so perfect that it was impossible to tell where they were.

MR. CALVIN W. RICE:—The attitude of the manufacturers towards the problem of cables for high potentials is very interesting. I have visited the principal factories, and want to say in behalf of manufacturers that there are several who have had full data for a number of years for the manufacture of cables for the potential mentioned in this paper, and have had testing transformers as large as 50 K.W for the testing of their product up to as high as 50,000 volts. I think there are four companies that can test as high as 50,000, and one can test as high as 110,000 volts. A cable that I purchased very recently has been tested—I state this just to show the ability—to 60,000 volts. There is in this city, for cables now being installed, a 400 K.W. transformer for testing the cables at 40,000 volts. I want to suggest something of the commercial conditions which probably obtained during the time of letting this contract. There has been a remarkable amount of cable business. The Philippine cable and the cable

to Cuba, Nome and other portions of the world, have demanded all the energies of the cable manufacturers, besides the home consumption, and I have no doubt that at the time this cable was projected there were some features of the specifications respecting delivery, or a guarantee which made it impracticable, or perhaps unprofitable, for the other companies which did not enter the competition, to have commercially undertaken this work. There are four or five companies that I can say without hesitation could undertake to build this line.

I am not familiar enough with the paper to ask questions without apology that is due the author for not reading it thoroughly before the lecture. I notice that he stepped up Y and stepped down $\triangle$, and would like to learn the advantage. Then there are two lines operated in multiple. In the operation of two lines in multiple where one is used as spare in case of trouble on the other line, I would like to ask the author if he puts in safety devices for the capacity of the total plant on each line, or for the capacity of half on each line.

I would like to learn the engineering feature considered in adopting the amount of insulation on this cable, both in the paper and the rubber; also the relative thicknesses between the insulation on the conductors and that in the jacket. I would like also to ask why a jacket construction was decided upon, if it was for any reason other than a commercial one—rather than three conductors having a total insulation on each conductor.

There is one gentleman whose name I would like to see added to the list to whom the author gives credit for engineering, who, from his modesty, we very seldom see in print, Mr. Francis O. Blackwell. He is responsible for a great deal of the successful engineering in long distance transmission of power that we have in America.

Dr. Schuyler S. Wheeler:—I would like to ask the last speaker a question. I understood him to say that there was in this city at the present time a dynamo of 400 k.w. capacity for testing up to 40,000 volts. I would like to inquire if there is any connection between the capacity of the dynamo and the voltage he wants to test, or if that is only accidental.

Mr. Rice:—The charging current for 25 cycles for the cables that are being installed in New York City at 40,000 volts and the longest cable which will extend down to the Battery, will require a transformer of 400 k.w. capacity.

Mr. C. E. Knox:—I would like to ask what is the relative cost of the rubber covered cables and the paper covered cables used underground?

Mr. Rice:—The rubber is about double that of the paper for this particular construction of cable such as I am using.

Mr. Floy:—I would answer that inquiry by saying that in this case instead of being double it was about 50% more.

DR. WHEELER:—I would like to ask once more if I am to understand that the insulation of the cable consumes 400 kilowatts.

MR. RICE:—It consumes 400 kilowatts apparent energy. I do not know what the power factor is. The volt amperes are 400,000.

MR. FLOY:—Are you testing in place the cables that you are installing now up to 40,000 volts?

MR. RICE:—We are not quite ready to test. It was simply a question of the delivery by the manufacturer of the transformer which came recently. It has been on order nearly a year, and the switchboard for operating it, etc., is not quite set up.

DR. WHEELER:—I want to ask once more—I think I understand what is meant by the kilowatts being apparent—in that case would it take an engine or belt drive capable of giving 400 kilowatts?

MR. RICE:—No, sir; it would not.

MR. EDWARD P. THOMPSON:—I am interested in knowing about the reliability of the potential indicator arrangement that the author has for indicating E.M.F. thirty miles off—whether it is found to allow for drop of electromotive force and so on, and whether it works as satisfactorily as it should for that purpose. What is your personal testimony? I am interested in knowing the fact?

DR. SHELDON:—I would like to know why you prefer glass insulation to porcelain, if there is any other reason than that of cost?

MR. FLOY:—I will try to answer this long list of questions. We use two-phase current for distribution instead of three-phase, because there were already installed single phase alternating current circuits for supplying current in the outlying districts, and the two-phase seemed to fit into that system a little more satisfactorily than the three-phase would. We use rotary converters, because in the center of the city they already had an Edison three-wire system, and it would have cost considerable to discard that system entirely, and use an alternating current for distribution. They had in use, a number of direct current motors, direct current lamps, etc., which would have been rendered useless.

I am glad to get so much light on this question of decrease in charging current as the cycles are increased. With regard to the use of voltage the opinion seems to prevail that I have made the statement that high voltage had not been used underground. Of course that is not the impression I intended to give, as we all know that high voltages have been used, 10,000 volts or slightly more in London for a number of years, and at Niagara Falls, I believe, they tested up as high as 20,000 volts some time ago, and 12,000 volts have been in constant use between St. Paul and Minneapolis for three years. I had never before known that

30,000 volts was commercially used in Paris this last summer, as I understand the President to state.

THE PRESIDENT:—Only as an exhibit.

MR. FLOY:—As to the voltage in the city as most of us know, that is 6600, I believe, and the only *test* that they have made on the cables that I have heard of, and I have talked with the companies that provided the cables, was a maximum of 25,000 volts. Mr. Rice says that when they get his apparatus in order they expect to go higher. Of course I am talking about what *has been* done.

Now, with regard to the cables, it does seem to me only fair that the companies who were enthusiastic about the manufacture of these high-tension cables should get what credit is due them, and a year ago at this time there were no other companies who were ready to undertake the manufacture of those cables on any specifications, whatever their reasons were I don't know, but that they may be ready *now*, because these cables have been put in operation and proved successful. But a year ago at this time there were no other companies I had any communication with, that were willing to consider these cables at all, and I communicated with all the important ones.

With regard to the connections, we planned to use Y connection on both stepping up and stepping down transformers, but we are also planning to use 250-volt rotaries. That would have allowed, with the transformers we planned, two transformers to each rotary. It was found necessary, later, to put in two rotaries of 110 volts each and operate them across the three-wire system in order to give us more flexibility in independently varying the voltage on either side of the Edison three-wire system. In making this change and without increasing the number of step-down transformers, we had to use a delta connection at the sub-station or else run the risk of one transformer burning out and shutting down the whole direct current plant. That was the reason for the change and the use of the delta connected step down transformers.

With regard to the safety devices, I may say that we do not use any safety devices whatever, the plan being to stall the water-wheels before we let go. There are no fuses or circuit breakers on anything between the water-wheels and the feeders of the switchboards in St. Paul.

Mr. Thompson asked about the indicators. I cannot say anything about them from my own experience. In this plant the indicators have not been put in working condition. Their series transformers have not yet been supplied by the manufacturer, and all I know is the indicators have been used in other places in the West I understand, very satisfactorily.

With regard to the insulators, we used glass because they were cheaper, and because they seemed just as satisfactory, and do not require the minute inspection on installation that porcelain insulators do.

Naturally these figures as to costs of the plant are most interesting. We would all like to know what they are. At the same time I do not feel quite at liberty to disclose very much along that line. Of course it is easy enough for any one to sit down and figure the cost of our copper and come pretty close to it; so I do not have any hesitation in saying that the copper cost about $30,000 for the 24 miles. We would have saved between $3,000 and $4,000 in substituting aluminium for copper.

Mr. F. C. Bates:—I should like to change a possible impression that may have been created by Mr. Floy's statement, that no other cable manufacturers other than those mentioned in this paper, could be induced to bid on his specifications for this installation.

In Mr. Floy's efforts on behalf of his clients, his specifications were drawn in such a way as to put the greater part of the financial risk on to the manufacturer. As it was an installation involving some risk, and as at that time there was a great deal of attractive business offered, *at least one manufacturer* declined to bid purely on commercial grounds, and not from an engineering standpoint.

Mr. Edward P. Thompson:—Mr. Floy said that more credit should be given to the two companies who laid conductors underground to carry 25,000 or more volts. Of course it is to their credit to be so enterprising as to do it, and it may be to their discredit if it does not work well. But the point is that the names of the companies do not seem to be given in the paper, although names are given very freely, and I think it is perfectly proper—trademark names and names of instruments, and so on. But I do not find the names of those two companies, and in making these remarks I would say that I have no connection with them, and I do not know who they are, but I do not see any reason why their names should not be mentioned, because we cannot give them credit unless we know who they are.

The Secretary:—The position taken by Mr. Bates is exactly the same that I took in talking with one of the gentlemen who examined this paper as to what I would have done had I been a manufacturer of cables. It appeared to me that if there was any other way of keeping the plant busy, I should not undertake to make cables for an experiment of that kind, and put so much capital into them and guarantee them for five years out West, and under unusual conditions, or conditions with which I was not familiar.

In regard to Mr. Thompson's inquiry in reference to the make of cables, I think if he is familiar with the cable market he will readily know who the makers of the National and Safety cables are.

Mr. Mailloux:—With reference to the interesting remarks made about the relative cost of aluminium and copper wire, I may state that I have had occasion to figure it recently in con-

nection with some transmission lines which were in prospect, and I found that with copper at 21½ or 22 cents, the cost of line material for the same conductivity, using aluminium, bore to copper the relation of about 17 to 22. With copper wire at 21½ or 22 cents a pound, the same conductivity and carrying capacity with aluminium wire would cost the same as if copper were reduced to about 17 cents. Hence if copper falls down to 17 cents, and the price of aluminium remains stationary, the same conductivity with the two metals, costs about the same. The cost of the line, of course, includes a constant plus, a variable quantity, the constant being the cost of the pole line, which, for a given case, is pretty nearly independent of all conditions, including the size of line, because ordinary precaution dictates the use of certain size poles and a certain spacing, etc., which are very little changed, no matter what may be the number of lines put upon the poles. The number and size of cross-arms may be changed, but these do not affect the cost very much. The number and cost of insulators, for a given case, may be considered constant. On the other hand, the cost of the metal portion of the line will increase with the conductivity. It will also increase with the number of lines, if two or more complete lines are to be put upon the same poles; the increase being largely due to the increase in number of insulators.

With regard to underground cables, I have been surprised to find that there is much difference in the method of constructing them here and in Europe. Some three years ago I had occasion to investigate the matter carefully in Eastern Europe for some clients who were interested in having the subject studied for them. I was surprised to find that in Austria, in Hungary, and even in the eastern portion of Germany, cables are being made for use with pressures varying from 2,000 to 12,000 volts, which, outwardly at least, are very little different from what we call "triple braid weather-proof wire" in this country. I visited two large factories where cables for high pressures were being made by wrapping the copper conductor with three simple braids of cotton or jute, or sometimes with linen or cotton thread, the braids being somewhat thick. For a 10,000 volt cable the total thickness would be perhaps from one-eighth to three-sixteenths of an inch. Each conductor receives its own wrapping; and two, three, or more of these conductors (as many as are required for the purpose), are bunched together, and the cable sheath of lead is put over them, after they have been treated with an insulating compound. The cables are insulated simply by baking the moisture out of them and by passing them through a compound, the exact composition of which is a secret. I have seen these cables tested up to 25,000 volts, the entire cables being put into a vat of water just as they came from the factory, with the two free ends sticking out of the vat, and all the conductors being coupled together in parallel, and the source of potential

being connected between the cables and the water in the vat, so as to give every possible chance for leakage. I have seen cables with one or two wrappings of this braid, of two or three millimeters total thickness, treated with a compound and covered with a sheathing of lead, subjected to pressures of 15,000 volts for an indefinite length of time without apparent effect. The central station manager in one of the large cities in Hungary told me that underground work would scarcely be possible there unless they could obtain underground cables at much lower cost than that at which they could be obtained, if rubber or any expensive insulation had to be used. It is a matter of some surprise to me, therefore, to find that, in this country, we have to resort to such expensive processes of cable manufacture in order to obtain cables that can withstand the pressure of 6,000 to 10,000 volts.

MR. RICE:—I would like to speak upon the point of the necessity of a large insulating wall for high pressures. We have cables in New York City which have been in service about eleven years, and we have had considerable experience, and we have found from actual experience the necessity of it, and for the 6600-volt work we consider it essential that there be at least 10/32 of rubber insulating wall, of a compound as good as that mentioned in the paper to-night, *i. e.*, about 35 per cent. of rubber compound, in order to insure an absolutely safe cable.

In connection with Mr. Mailloux's remarks regarding the testing of cables with jute or cotton insulation at such high voltages, I should like to ask the capacity of the transformers that were used in testing, and if you observed how the potential was measured at the time of the test.

MR. MAILLOUX:—As near as I can recollect, in one of the factories that I visited, the machine used was of about 25-kilowatts capacity. It generated a low electromotive force which was raised by step-up transformers of sufficient capacity (apparently suitable for the machine), and the potential was measured by an electrostatic voltmeter of the Kelvin type; so that there could be no doubt as to the pressure. The voltmeter was connected directly at the terminals of the transformer. I have seen this alternating pressure remain in application for fifteen or twenty minutes. In fact, I was allowed to let it continue as long as I wished it to stay. I did not care to have it tried any longer than ten minutes. I was perfectly satisfied after even five minutes.

[Adjourned.]

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, January 9th, 1901.

The 149th meeting of the INSTITUTE, which was organized as a dinner, was held at "The Arena," 41 West 31st Street, this date, and the topic announced for discussion was "Electricity in the Last Century and in This."

The meeting was called to order by President Hering at 9.55 o'clock. The following resolution was unanimously adopted:

Whereas, The Committee on Coinage, Weights and Measures of the House of Representatives has favorably reported by a unanimous vote bill, H. R. 11350, and

Whereas, On account of the entire absence of official electrical and photometric standards and the practical absence of standardizing facilities for electrical measuring apparatus, it is

Resolved, That we, THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, in meeting assembled this ninth day of January, 1901, do strongly urge the Honorable Speaker of the House of Representatives and the Honorable Members of the Committee on Rules to fix an early date for the consideration of this bill so vitally important to the scientific, educational, manufacturing and especially to the electrical interests of the country.

The President then invited Past-President Martin to act as Toastmaster for the evening, and upon his request the following gentlemen spoke upon the topic announced for the occasion: Dr. N. S. Keith, founder of the INSTITUTE, Past-President Arthur E. Kennelly, Past-President Francis B. Crocker, Past-President Frank J. Sprague, and Prof. W. H. Hallock.

[As finally approved by Council on April 26th, 1901, and ordered printed. A typewritten copy was presented at the regular meeting of the INSTITUTE on the same date, and notice given that the proposed Constitution would be brought up for consideration at the Annual Meeting, May 21st, 1901. Proxies should be made out in the names of members who will attend that meeting, otherwise they cannot be used.]

PROPOSED CONSTITUTION

OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

ARTICLE I.

1. The name of this association shall be the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

2. Its objects shall be the advancement of the theory and practice of Electrical Engineering and of the Arts and Sciences connected with the production and utilization of electricity, and the maintenance of a high professional standing among its members. Among the means to this end shall be the holding of meetings for the reading and discussion of professional papers and the publication of such papers, discussions and communications as may seem expedient.

ARTICLE II.

MEMBERSHIP.

1. The corporate members of the INSTITUTE shall be designated as Members and Associates. Members and Associates shall be equally entitled to all of the rights and privileges of the INSTITUTE, except eligibility to the offices of President and Vice President, which shall be limited to Members; and Members only shall be entitled to a diploma. There shall also be Honorary Members, who shall be entitled to all the rights and privileges of the INSTITUTE, except the right to vote for officers and hold office.

2. A Member shall have been an Associate, and at the time of his transfer to membership he shall be not less than twenty-seven years of age, and shall be:

a. A Professional Electrical Engineer; or

b. A Professor of Electrical Engineering; or

c. A person who has done important original work, of recognized value to electrical science.

3. To be eligible to membership as a professional Electrical Engineer, the applicant shall have been in the active practice of his profession for at least five years; he shall have had responsible charge of work for at least two years, and shall be qualified to design as well as direct electrical engineering works. Graduation from a School of Engineering of recognized standing shall be considered the equivalent of one year's active practice.

4. To be eligible to membership as Professor of Electrical Engineering, the applicant shall have been in responsible charge of a course of Electrical Engineering at a college or technical school of recognized standing, for a period of at least two years.

5. An Associate shall be a person who is interested in or connected with the study or application of electricity.

6. Honorary Members may be chosen from among those who have rendered acknowledged, eminent services to electrical engineering or its allied sciences.

ARTICLE III.

Admission, Transfer and Expulsion of Members.

1. Honorary Members shall be proposed in writing by at least ten Members, and may be elected only by the unanimous vote of the Board of Directors, a ballot in writing to be forwarded by Members absent from the Directors' meeting. The election of an Honorary Member shall be deemed invalid if an acceptance is not received within six months after the date of his election.

2. An application for admission to the Institute as Associate shall be made in a form prescribed by the Board of Directors, and shall refer to at least three members or associates.

3. An applicant for transfer from the grade of Associate to that of Member shall be made in a form prescribed by the Board of Directors, and shall embody a full record of the general technical education of the candidate, and of his professional career. It shall be signed by the applicant, and shall refer to at least five Members

by whom he is personally known. Each of these references shall be requested by the Secretary to fill out a prescribed confidential form, to be addressed to the Board of Directors. No such application for transfer shall be considered until at least five favorable replies have been received. The Board of Directors, or the Board of Examiners, in the event of failure of replies, or receipt of unfavorable replies, may call upon the applicant to furnish additional names. Should an applicant for transfer certify that he is not personally known by five members, the Board of Examiners may accept references for the deficiency to professional engineers of standing.

4. The reference to Members to whom he is personally known may be waived in case of foreign applications; but the applicant shall in that case refer to at least two professional engineers of recognized standing.

5. The Secretary shall issue at stated intervals to each Member and Associate whose address is known, a list of new applications for admission to the INSTITUTE, with the request that the Members and Associates make written communication to the Board of Directors, in case of objection to any of the candidates named. The Board of Directors shall not act upon any name until at least twenty days after the date of issue of said list.

6. All elections to Associate Membership, and transfers to grade of Membership, shall be by vote of the Board of Directors; two negative votes shall exclude a candidate.

7. The Board of Directors may refuse to elect or transfer any applicant whose character, reputation or professional conduct would make him, in the opinion of the Board of Directors, an undesirable member.

8. A member of any grade in the INSTITUTE may resign his membership by a written communication to the Secretary, who shall present the same to the Board of Directors; whereupon, if all his dues or other indebtedness have been paid, his resignation shall be accepted

9. Upon the written request or ten or more Members or Associates that, for cause stated therein, a Member or Associate of the INSTITUTE be expelled, the Board of Directors shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. He shall then have the right to present a written defence, and to appear in person before a meeting of the Board of Directors, of which meeting he shall receive

notice at least twenty days in advance. Not less than two months after such meeting, the Board of Directors shall finally consider the case, and if in the opinion of the Board of Directors a satisfactory defence has not been made, and the accused Member has not in the meantime tendered his resignation, he shall be expelled.

ARTICLE IV.

DUES.

1. The entrance fee, payable on admission to the INSTITUTE, shall be five (5) dollars. A fee of ten (10) dollars shall be paid on transfer to the grade of Member, which shall include the fee for a diploma.

2. The annual dues shall be fifteen (15) dollars for Members and ten (10) dollars for Associates.

3. The annual dues of Members and Associates residing in foreign countries other than Canada and Mexico, shall be ten (10) and five (5) dollars, respectively.

4. Honorary Members shall be exempt from all payments.

5. Persons elected after six months of the fiscal year have expired, shall pay one-half of the amount of dues for that fiscal year.

6. A Member or Associate in good standing, by the single payment of two hundred (200) dollars in addition to his entrance fee, shall become exempt from all future payments for dues or transfer fee. All money thus paid shall be invested as a permanent fund, of which the interest only shall be subject to appropriation for current expenses.

7. A Member or Associate who has been dropped as delinquent may be reinstated by the Board of Directors upon payment of all back dues, retaining his original date of election, and shall be entitled to a complete file of the published TRANSACTIONS corresponding with said payment, provided the same are in stock; or such Member or Associate shall have the option of reelection to the same grade, and payment only of his indebtedness up to the time he was dropped from the list.

ARTICLE V.

OFFICERS.

1. The officers of the INSTITUTE shall be a President, six Vice-Presidents, twelve Managers, a Secretary and a Treasurer, who shall hold office as follows:

2. The President, the Secretary and the Treasurer for one year, the Vice-Presidents for two years, and the Managers for three years. The President, a Vice-President or a Manager shall not be eligible for immediate reelection to the same office. At each annual meeting, a President, three Vice-Presidents, four Managers, a Secretary and a Treasurer shall be elected in the manner prescribed below, whose terms of office shall commence upon the fourth Friday in September.

3. A vacancy in the office of President shall be filled by the senior Vice-President; a vacancy in the office of Vice-President shall be filled by the senior Manager. Seniority between officers of same rank and date of election shall be determined by the date of their election as Associates. All other vacancies shall be filled by the Board of Directors for the unexpired term. Such succession to office or appointment by the Board of Directors shall not render an officer ineligible for immediate election to the same office.

4. No officer shall receive, directly or indirectly, any salary, compensation or emolument from the INSTITUTE, either as such officer or in any other capacity, unless authorized by a vote of a majority of the entire Board of Directors.

5. No officer shall be interested, directly or indirectly, in any contract relating to the operations conducted by the INSTITUTE, nor in any contract for furnishing supplies thereto, unless expressly authorized by the by-laws and by the unanimous vote of the Board of Directors.

6. To provide for the officers already holding office when this Constitution shall go into effect, their terms shall be considered as dating from the time of the Annual Meeting as set forth in the Constitution which this Constitution supersedes, instead of from the fourth Friday in September, as this Constitution specifies; and nothing in this Constitution shall operate to exclude from office any officer elected under the previous Constitution.

ARTICLE VI.

ELECTION OF OFFICERS.

1. During the first week in February of each year, the Secretary shall mail or deliver to each Member and Associate of the INSTITUTE residing in the United States, its territories, Canada or Mexico, a list of all Members and Associates, together with a form showing the offices to be filled at the ensuing annual election in May, and

containing the names of the incumbents and a copy of sections 1 and 2 of this article, with the request that nominations be made for the various offices to be filled. These nominations shall not be signed, and shall be enclosed in an envelope identified on the face by the name of the sender. To be considered, nominations must reach the Secretary prior to March first.

2. The Secretary shall submit to the Board of Directors a classified list of all nominations received, from which the Board of Directors shall prepare, during the month of March, a complete ticket, to be headed: "Directors' Nominees," containing the names of those whom the Board of Directors deem best suited for the offices falling vacant; provided that upon the request of two Directors at the meeting at which the "Directors' Nominees" ticket is prepared, the name of a second nominee for President shall be placed on the ticket, selected from the four names receiving the highest number of votes for President; and provided further, that the names for the office of Vice-President shall be selected with a view to maintaining a geographical distribution of the incumbents of this office. This ticket shall be printed on the same sheet with a second list, headed: "General Proposal List," containing all the eligible names proposed and the number of votes cast for each; provided that no name shall appear which shall not have received at least two per cent. of the entire number of votes cast.

3. The voting for officers shall be restricted to be names on the General Proposal List provided for in Section 2 of this Article. This sheet, together with an envelope on which shall be printed the title of the INSTITUTE, the name and address of the Secretary, and the words: "Official Voting Envelope—Enclosing a Ballot Only," shall not later than the 15th day of April, be mailed by the Secretary to every Member and Associate in good standing, together with a copy of Sections 3 and 4 of this Article; provided, that any qualified Member or Associate not having a ballot and envelopes shall be entitled to obtain them from the Secretary at any time before the ninth day of May.

4. All names voted for shall be written, printed or otherwise marked on a single ticket or ballot, which shall be enclosed in a sealed, unmarked and unidentified inner envelope of any suitable character, which shall in turn be enclosed either in the "Official Voting Envelope" (received from the Secretary), or any other envelope, marked on its face; "Non-Official Voting Envelope—Enclosing a Ballot Only." The outer envelope of either class shall be identified by the name of the sender on its face, shall be sealed,

and in order to be counted, shall reach the Secretary not later than the ninth day of May. The Secretary shall preserve, unopened, all ballots received after the ninth day of May.

5. The President at the Directors' meeting to be held in April, shall appoint, subject to the approval of the Board of Directors, five Members or Associates, not members of the Board of Directors, to constitute the Committee of Tellers; should this Directors' meeting not be held, the President shall appoint this Committee by letter to the Secretary, who shall notify the members thereof.

6. Any Member or Associate who shall deliver to the Secretary on or before the ninth day of May, a written petition signed by at least twenty Members or Associates, stating their desire that he be a member of the Committee of Tellers, shall also be a member of that Committee; provided that the aforesaid signatures shall not have appeared on another similar petition.

7. The Committee of Tellers shall meet at the office of the INSTITUTE as soon after the ninth day of May as possible, and shall receive, unopened, all ballots from the Secretary, who shall also make to it a written report of the number of ballots received on and before and after the ninth day of May. It shall forthwith proceed, in secret, to count the vote, and shall prepare and sign a report of the results of the vote, which shall be sealed, and shall remain in the possession of the Chairman of the Committee, who shall hand this report to the presiding officer at the ensuing annual meeting. The presiding officer shall then cause this report to be read, and shall declare duly elected the eligible persons receiving the greatest number of votes for the respective offices.

ARTICLE VII.

MANAGEMENT.

1. The affairs of the INSTITUTE shall be managed by a Board of Directors under this Constitution and the general provisions of the laws under which it is incorporated. The Board of Directors shall consist of the officers of the INSTITUTE and the two junior Past-Presidents.

2. The Board of Directors shall have such powers and duties as are prescribed by statute for a Board of Directors.

3. The Board of Directors shall direct the investment and care f the funds of the INSTITUTE, shall make appropriations for

specific purposes, shall pass upon all applications for admission or for transfer, shall act upon all questions of expulsion of members, shall appoint all employees and fix their salaries, and in general shall direct the business of the INSTITUTE, either itself or through the officers and committees.

4. The Board of Directors shall prepare and adopt a series of by-laws which shall govern its procedure and that of its committees, under this Constitution. Such by-laws shall be adopted or may be amended by a two-thirds vote of a quorum of the Board of Directors; provided, that the text of a proposed by-law or amendment shall be furnished to each member of the Board of Directors at least ten days before the meeting at which a vote of the same will be taken.

5. The President shall have general supervision of the affairs of the INSTITUTE, under the direction of the Board of Directors. He shall preside at the meetings of the INSTITUTE and of the Board of Directors at which he may be present, and shall be ex-officio member of all committees. He shall deliver an address at the Annual Convention. The Vice-Presidents, or in their absence, the Managers, in order of seniority, shall preside at meetings of the INSTITUTE and the Board of Directors in the absence of the President, and shall discharge his duties in case of a vacancy in the office. The President shall, at the meeting of the Board of Directors to be held on the fourth Friday in September, appoint the following Standing Committees: A Board of Examiners of five members; a Library Committee of five members; a Committee on Papers of five members; an Editing Committee of three members, a Committee on Finance of three members. He may also appoint temporary committees from time to time. The members of the Finance Committee shall all be members of the Board of Directors. All other standing committees shall include at least one member of the Board of Directors. All Members of the Board of Examiners shall be full members of the INSTITUTE.

6. The Secretary shall receive all moneys, and deposit them in the name of the INSTITUTE, reporting such deposit to the Treasurer, who shall receipt for the same. The Treasurer and the Secretary shall invest such funds as may be ordered by the Board of Directors. They shall also pay bills when audited by the Committee on Finance and approved by the Board of Directors. The Treasurer shall make an annual report and such other reports as may be prescribed.

7. The Secretary shall be, under the direction of the President and the Board of Directors, the Executive Officer of the INSTITUTE.

He shall attend all meetings of the INSTITUTE and of the Board of Directors. He shall prepare the business for it, and record the proceedings thereof; he shall collect and deposit, subject to the order of the Treasurer, all moneys due the INSTITUTE. He shall personally certify the accuracy of bills or vouchers on which money is to be paid, and shall draw and countersign all cheques, and these shall be signed by the Treasurer when such drafts are known to him to be proper and duly authorized by the Committee on Finance, and in accordance with warrants executed by the Secretary. He shall have charge of the books and accounts of the INSTITUTE, and shall furnish monthly to the Board of Directors a statement of receipts and expenditures and monthly balances. He shall present annually to the Board of Directors a balance sheet, and from time to time shall furnish such statements as may be required. He shall conduct the correspondence of the INSTITUTE, and keep full records. He shall be in responsible charge, under the President, the Board of Directors, and the Library Committee, of all the property of the INSTITUTE. He shall be responsible for the work of all employees of the INSTITUTE. He shall perform such other duties as may be assigned to him. His entire time must be devoted to the affairs of the INSTITUTE, unless otherwise authorized by the Board of Directors. He shall be paid a salary to be fixed by the vote of a majority of the entire Board of Directors.

8. The Board of Directors may, if deemed expedient, appoint assistants to the Secretary; one of these may hold the title of Assistant Secretary, who shall be under his immediate direction and shall aid him in all matters.

9. The Board of Directors may delegate any or all of its powers to an Executive Committee of seven members, consisting of the President, the Secretary, and the Treasurer ex-officio, and four other members of the Board of Directors, which committee shall conduct the affairs of the Board of Directors between its meetings.

10. All committees shall be directly responsible to the Board of Directors, and shall act under its directions. The Board of Directors may, at any time, at its own discretion, remove any or all members of the committees and appoint others. The terms of the members of all standing and temporary committees shall terminate on the fourth Friday in September of each year, when the incoming President shall reconstitute the membership of all standing committees, and of such temporary committees as may have further duties to perform.

11. The reports or actions of all Committees shall be addressed to the Secretary, and shall be by him referred to the Board of Directors

12. *The Committee on Finance* shall have direct supervision of the financial affairs of the INSTITUTE. It may employ an expert accountant to assist in auditing the accounts. It shall approve all bills before payment, and shall make recommendations to the Board of Directors as to the investment of moneys, and upon all specific appropriations. No payments other than routine office expenses shall be made by the Secretary or Treasurer except upon the authorization of the Committee on Finance.

13. *The Library Committee* shall have general supervision of the Library and the rooms of the INSTITUTE, and the property therein. The Secretary shall be responsible to the Library Committee for his care of the property of the INSTITUTE. The Committee shall make recommendations with reference to books, and shall direct expenditures for books or other articles of permanent value, of such sums as may be appropriated for these purposes.

14. *The Committee on Papers* shall have general supervision of the papers to be presented to the INSTITUTE at its meetings, and of the discussions thereon. This Committee shall have the responsibility of collecting papers. It shall not accept papers from non-members without special authorization from the Board of Directors.

15. *The Editing Committee* shall edit all discussions of the papers presented. It shall be the duty of this Committee to limit as far as possible the amount of matter to be printed in the discussions. The printed discussions shall preferably be put in the third person. This Committee shall decide all questions regarding the publication of papers, discussions and communications.

16. *The Board of Examiners.* All applications for membership or for transfer that may be received by the Secretary shall be referred by him to the Board of Examiners, who shall pass upon the qualifications of the various applicants and shall report their recommendations to the Board of Directors, who shall pass upon the recommendations of the Board of Examiners.

17. The Board of Directors may, at its discretion, appoint Local Honorary Secretaries to represent the INSTITUTE in various parts of the world.

18. The following Members shall constitute a quorum of the Board of Directors:

For all business prescribed by statute for a Board of Directors—Twelve Members.

For Expulsion of Members—Fifteen Members.

For all other business—Five Members.

19. The "vote of the Board of Directors" shall in all cases be the vote of a majority of the Members thereof present when the quorum required for the particular occasion is present.

ARTICLE VIII.

MEETINGS.

1. The Annual Meeting of the INSTITUTE shall be held on the third Tuesday of May, when a report of the proceedings of the INSTITUTE for the past fiscal year shall be furnished by the Board of Directors. This report shall be verified by the President, Treasurer and Secretary and a majority of the officers. It shall show: The whole amount of real and personal property owned, where located, where and how invested; the amount and nature of the property acquired during the last fiscal year and the manner of its acquisition; the amount applied, appropriated or expended during the year, and the purposes, objects or persons to or for which such applications, appropriations or expenditures have been made; the names and places of residence of persons who have been admitted to Membership in the INSTITUTE during such year; and all other facts bearing upon the status of the INSTITUTE. This report shall be filed with the records of the INSTITUTE and an abstract thereof entered in the minutes of the proceedings of the Annual Meeting. The reports of all officers shall be presented at the Annual Meeting, and the vote for officers for the ensuing year shall then be announced. Any other business may be brought before this meeting.

2. There shall also be held an Annual Convention of the INSTITUTE at some time after the Annual Meeting and before the first of December following, for the presentation and discussion of professional papers, and for the transaction of such other business as may be brought before it. The time and place of such Convention shall be fixed by the Board of Directors.

3. Other meetings of the INSTITUTE may be held at such time and places as the Board of Directors shall select, at which no business affecting the organization or policy of the INSTITUTE shall be transacted. Notice of all meetings shall be given by mail, or otherwise, to all Members and Associates, at least ten days in advance.

4. Every question which shall come before any meeting of the INSTITUTE shall be decided, unless otherwise provided by this Constitution, by the vote of a majority of a quorum.

ARTICLE IX.

STATE AND DISTRICT ORGANIZATIONS.

1. In each State or Territory of the United States in which there are fifty or more Members and Associates, the Board of Directors may authorize the formation of a State organization, for the purpose of more effectively carrying out the objects of the INSTITUTE.

2. The resident Members and Associates thus organized in any State shall have the privilege of being represented at the Annual Convention by one delegate to each fifty members. Such delegates shall be nominated by the resident Members and Associates of each State, by selecting names from the membership in the State, a list of which shall be forwarded by the Secretary, who shall also prepare and distribute the necesssary circulars for that purpose. The appointment of delegates shall be made by the Board of Directors in conformity with the expressed wish of the members. The Board of Directors shall also appoint alternate delegates, who shall serve in the absence of any delegate.

3. Official delegates thus appointed will be required to attend the Annual Convention, and shall be entitled to receive from the Treasury a sum of money sufficient to cover the cost of their railroad fare. They may cast as many votes as they shall hold proxies from their constituents upon any question brought before the Annual Convention.

4. The appointment as delegate shall not debar the incumbent from appointment or election to any other office in the INSTITUTE.

5. The Members and Associates of a State or Territory not entitled to a delegate may, upon request to the Board of Directors, be authorized to join with the Members and Associates of a contiguous State or States, and form a District, which, for the purpose of this Article, shall be considered as being one State, but shall be called a District, taking its name from the State within that District having the largest membership.

6. The Dominion of Canada and the Republic of Mexico shall

each be considered as States, under the provisions of this Article.

7. Any State or Territory having a less number than fifty members may be represented by a delegate upon request to the Board of Directors, but such delegate shall not be entitled to receive from the Treasury of the INSTITUTE any portion of his expenses.

ARTICLE X.

GENERAL.

1. A quorum of the INSTITUTE shall consist of one-tenth in number of the total number of Members and Associates, residing in the United States and its territories, in Canada and in Mexico, as printed in the list provided for by Section 1, Article VI., issued each year, prior to the Annual Meeting

2. Every Member or Associate entitled to vote at any meeting may so vote by proxy. Every proxy shall be executed in duplicate in writing by the Member or Associate himself, or by his duly authorized attorney, and one copy thereof filed with the Secretary before the date on which it is to be voted. No proxy shall be valid after the expiration of eleven (11) months from the date of its execution, unless the Member or Associate executing it shall have specified therein the length of time it is to continue in force, which shall be for some limited period. Every proxy shall be revocable at the pleasure of the person executing it.

3. For the purpose of electing officers, proxy voting shall be practiced only as provided in Article VI., and the Committee of Tellers therein named shall be considered a proxy Committee for the definite purpose stated.

4. The fiscal year of the INSTITUTE shall terminate with the thirtieth day of April.

ARTICLE XI.

AMENDMENTS.

1. Proposals to amend this Constitution shall be made in writing to the Board of Directors , and signed by at least twenty-five Members or Associates, and shall reach the Secretary not later than February first; the Board of Directors shall consider such proposals, and if in its opinion they are in accordance with

the laws under which the INSTITUTE is organized, shall order the Secretary to send out a letter ballot upon such proposals. Votes, to be considered, shall be received not later than the ninth day of May. The Secretary shall refer these votes unopened to the Committee of Tellers, which shall count such votes and make a sealed report to the Board of Directors. This report shall be read at the Annual Meeting. An affirmative vote of a majority of the qualified Members and Associates shall be necessary to secure the adoption of an amendment.

2. Amendments so adopted shall take effect twenty days after their adoption; provided, that the officers of the INSTITUTE at the time any amendments become effective shall continue in office until the next Annual Meeting.

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